

**Preliminary Water Quality Management Plan  
(Preliminary WQMP)  
for  
Coto De Caza Estates  
Tentative Tract 17325**

**Prepared for  
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**February 5, 2010**

## OWNER'S CERTIFICATION

### Preliminary Water Quality Management Plan for Coto De Caza Estates Tentative Tract 17325

This Water Quality Management Plan (WQMP) for the Coto De Caza Estates has been prepared for Khalda Development, Inc. by Robert Beers. This Preliminary WQMP is intended to comply with the requirements of the County of Orange Tentative Tract 17325 preparation of a project-specific Preliminary WQMP.

The undersigned, while it owns the subject property, is responsible for the implementation of the provisions of this plan and will ensure that this plan is amended as appropriate to reflect up-to-date conditions on the site consistent with the current Orange County Drainage Area Management Plan (DAMP), and the intent of the stormwater and urban runoff NPDES Permit and Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the incorporated Cities of Orange County under the jurisdiction of the Santa Ana Regional Water Quality Control Board. A copy of this Preliminary WQMP will be maintained at the project site or project office.

This Preliminary WQMP will be reviewed with the facility operator, facility supervisors, employees, tenants, maintenance and service contractors, or any other party having responsibility for implementing portions of this Preliminary WQMP. At least one copy of the approved and certified copy of this Preliminary WQMP shall be available on the subject property in perpetuity. Once the undersigned transfers its interest in the property, its successors-in-interest shall bear the aforementioned responsibility to implement and amend the Preliminary WQMP.

\_\_\_\_\_  
Owner's Signature                      Date

\_\_\_\_\_  
Owner's Printed Name

\_\_\_\_\_  
Owner's Title/Position

Khalda Development, Inc.  
Company

22861 Tindaya, Mission Viejo, CA 92692  
Company Address

(949) 830-3444  
Telephone No.

## Table of Contents

<b>Section 1 Discretionary Permit(s), and Water Quality Conditions .....</b>	<b>1</b>
<b>Section 2 Project Description .....</b>	<b>2</b>
<b>Section 3 Site Description.....</b>	<b>4</b>
<b>Section 4 Best Management Practices.....</b>	<b>6</b>
4.1 Site Design BMPs .....	6
4.2 Source Control BMPs .....	7
4.2.1 Routine Non-Structural BMPs.....	7
4.2.2 Routine Structural BMPs .....	10
4.3 Treatment Control BMPs .....	12
<b>Section 5 Implementation, Maintenance and Inspection Responsibility for BMPs.....</b>	<b>14</b>
<b>Section 6 Location Map, Site Plan, and BMP Details .....</b>	<b>19</b>
<b>Section 7 Educational Materials .....</b>	<b>21</b>

### List of Tables

Table 1. Site Design BMPs .....	6
Table 2. Routine Non-Structural BMPs .....	7
Table 3. Routine Structural BMPs .....	10
Table 4. Treatment Control BMPs .....	12
Table 5. BMP Operation and Maintenance.....	16

### Appendix

A Conditions of Approval, Planning Commission Resolution [redacted] dated [redacted]

**I. Discretionary Permit Number(s), Water Quality Condition Number(s)  
and Conditions**

Proposed Tentative Tract 17325 is a subdivision of Parcel 1 of Parcel Map 89-107 (M.B. 246/33-35)

Condition of Approval Number (to be inserted) requires the preparation of a Water Quality Management Plan.

Conditions of Approval regarding the WQMP conditions shall be listed verbatim here when available.

## II. Project Description

Tentative Tract 17325 is a 127-acre site located in the County of Orange in the community of Coto De Caza. The project proposes to develop a 7 lot single-family subdivision, with development taking place within 11.8-acres of the site, and leaving the remaining 115 acres in natural open space. Natural and developed common open space areas and streets within the project will be private and maintained by the homeowners association. Landscape areas within residential lots within the tract will be maintained by the homeowners, the homeowners associate will maintain the natural open space areas, the developed common open space areas and the streets.

This project is categorized as a "Residential Development". The following are potential pollutants of concern:

### Potential Stormwater and/or Urban runoff pollutants

- Pathogens from food waste, animal waste, etc
- Heavy metals from vehicles in parking lot
- Nutrients from landscaping
- Pesticides from landscape maintenance
- Organic Compounds including petroleum hydrocarbons for vehicles
- Sediments from landscaping
- Trash and debris from general litter
- Oxygen-demanding substances from landscaping
- Oil & Grease from uncovered parking areas

A preliminary hydrology report has been prepared for the project. Per that report, the following information regarding the impervious surface areas of the proposed project is summarized:

### Description of Residential Development:

The seven residential lots will range in size from ½ -acre up to 2-acres in size, with house sizes ranging from 3,500 to 7,000 sf.

Assumptions for impervious areas within residential lots described as:

- House/Roof Area: 70' by 80'
- Pool/lot hardscape: 40' by 100'
- Driveways/parking areas: 40' by 30'
- Misc. walkways" 6' by 200'
- Total impervious area of 12,000 sf per lot
- Parking of cars to be surface parking on driveways and within covered garages

Description of Street Areas – Impervious Area

Streets have 34' right of way width (29' paving , curb & gutter – 5' pervious areas)  
Use 85% of street area(29/34) for impervious area calculations

Percentage of impervious surface area within project:

Area 1: Total Area = 2.8 Acres (Hydrologic Nodes 22 to 24)  
Residential Lots 3, 4, & 5 impervious area =  $3 \times 12,000 \text{ sf} = 36,000 \text{ sf}$ .  
Street area = 26,140 sf: 85% impervious area = 22,219 sf  
Total impervious area =  $36,000 + 22,219 = 58,219 \text{ sf} = \underline{1.34 \text{ acre}}$   
Total % impervious area =  $1.34/2.8 = 0.4786$  (47.9%).

Area 2: Total Area = 2.4 Acres (Hydrologic Nodes 24 to 26)  
Residential Lots 6 & 7 impervious area =  $2 \times 12,000 \text{ sf} = 24,000 \text{ sf}$ .  
Street area = 22,220 sf: 85% impervious area = 18,887 sf  
Total impervious area =  $24,000 + 18,887 = 42,887 \text{ sf} = \underline{0.98 \text{ acre}}$   
Total % impervious area =  $0.98/2.4 = 0.4083$  (40.8%).

Area 3: Total Area = 0.8 acre (Hydrologic Nodes 37 to 38)  
Portion of Residential Lot 7 (Assumed 5,000 sf)  
Street area = 0 sf.  
Total impervious area = 5,000 sf = 0.11 acre  
Total % impervious area =  $0.11/0.8 = .1375$  (13.8%)

Area 4: Total Area = 1.3 Acres (Hydrologic Nodes 42 to 45)  
Residential Lots 1 & 2 impervious area =  $2 \times 12,000 \text{ sf} = 24,000 \text{ sf}$ .  
Street area = 7,600 sf: 85% impervious area = 6,460 sf  
Total impervious area =  $24,000 + 6,460 = 30,460 \text{ sf} = \underline{0.70 \text{ acre}}$   
Total % impervious area =  $0.70/1.3 = 0.4385$  (53.8%).

Area 5: Total Area = 4.5 acres (Hydrologic Nodes 45 to 46, 56 to 70, 60 to 65)  
No residential lots  
Street Area = 53,060 sf: 85% impervious area = 45,101 sf  
Total impervious area = 45,101 sf = 1.04 acre  
Total % impervious area =  $1.04/4.5 = 0.2311$  (23.1%)

Total Development Area (Sum of Areas 1 – 5) = 11.8 acres  
Total impervious area = 4.17 acres  
Total % impervious area = 35.3%

### III. Site Description

The property is approximately 127 acres in size, with nominally 115-acres remaining as undisturbed open space. The property is located in Planning Area 10 of Coto De Caza, easterly of Vista del Verde, bounded on the west side by Tract 15425 (an existing single-family subdivision), and on the east side by natural open space owned by the Audubon Society. Access to the property is proposed by connection to Van Gogh Way. The existing topography of the project site consists of rolling hills with several ridges and ravines that convey flows through the project site to the west towards Tract 15245 and Vista del Verde.

The existing property is undeveloped open space, largely covered with coastal sage scrub, groupings of coastal live oak trees, chaparral and annual grasses. It is estimated that the property's existing percentage coverage is in the range of 75% to 90% (hydrologic \_ "good cover").

The developed portion of the project will be nestled between woodland and shrub areas, and will be graded in a manner so as not to impede the natural drainage courses of the rolling hills. Catch basins and onsite storm drains will be constructed in order to adequately capture and convey and distribute storm runoff to areas so as to not adversely impact downstream properties.

The property is zoned Rural Residential which allows up to a gross density of 1 d.u. per acre. The majority of the property is comprised of soils in Hydrologic Soil Group Type "B", with small pockets of Hydrologic Soil Type "D".

In the existing condition, 100% of the project site is pervious, with a hydrologic cover of "good". Within the 11.8-acre portion of the site being developed with 7 lots, the impervious area will be approximately 4.17-acres, for an impervious area fraction of 35.3%. When considering the entire 127 acre property, the impervious area fraction is 3.28%.

There are no known Environmentally Sensitive Areas (ESAs) or Areas of Special Biological Significance within the vicinity of the project.

#### **Project Proximity to Receiving Waters**

The Project is located within the jurisdictional boundaries of the San Diego Regional Water Quality Control Board (Region 9) within the San Juan Hydrologic Basin (Area 1) – Mission Viejo Hydrologic Area, sub-basin number 1.24 "Gobernadora" Watershed area.

Once onsite flows reach the western boundary of the project, the project flows are conveyed towards Vista del Verde in natural canyon drainage areas that are along the northerly and southerly edges of Tract 15425, where the flows are conveyed through Vista del Verde into Canada Gobernadora Creek which flows southerly to its confluence with San Juan Creek, and thence flows to the Pacific Ocean.

**Water Quality Concerns**

San Juan Creek is listed in Category 5 in 2010 Clean Water Act 303(d)/305(b) Integrated Report for the San Diego Region.

The Pollutants of Concern for which the receiving waters are listed as impaired in the Integrated Report are:

DDE (Dichlorodiphenyldichloroethylene), Indicator Bacteria, Phosphorus, Selenium, Total Nitrogen as N, & Toxicity.

**Hydrologic Conditions of Concern**

The project will not create any hydrologic conditions of concern since the project will ultimately discharge in to San Juan Creek, which is maintained by the Orange County Flood Control District.

#### IV. Best Management Practices

The project shall minimize the area of disturbance in grading of the residential lots, and shall utilize existing natural drainage channels where feasible, while preserving approximately 90% of the site (115 acres) as natural open space.

##### IV.1 Site Design BMPs

Table 1. Site Design BMPs

Technique	Included?		If no, state justification.
	Yes	No	
Minimize Directly Connected Impervious Areas (DCIAs) (C-Factor Reduction)	XX		
Create Reduced or "Zero Discharge" Areas (Runoff Volume Reduction) <sup>1</sup>	XX		
Minimize Impervious Area/Maximize Permeability (C-Factor Reduction) <sup>2</sup>	XX		
Conserve Natural Areas (C-Factor Reduction)	XX		

- 1 Detention and retention areas incorporated into landscape design provide areas for retaining and detaining stormwater flows, resulting in lower runoff rates and reductions in volume due to limited infiltration and evaporation. Such Site Design BMPs may reduce the size of Treatment Control BMPs.
- 2 The "C Factor" is a representation of the ability of a surface to produce runoff. Surfaces that produce higher volumes of runoff are represented by higher C Factors. By incorporating more pervious, lower C Factor surfaces into a development, lower volumes of runoff will be produced. Lower volumes and rates of runoff translate directly to lowering treatment requirements.

The project will maximize the permeable area provided onsite within each lot by providing landscape areas along the site perimeter. Opportunities to maximize site infiltration will be incorporated through the use of infiltration trenches, and directly connection roof runoff to underground pipes and infiltration trenches.

The owner shall consider the use of open-jointed paving materials or permeable surfaces such as pervious concrete, porous asphalt, unit pavers, and granular materials for onsite walkways, trails, patios, driveways, and onsite parking areas.

Street widths have been reduced to minimize the impervious area within the project.

The project shall incorporate planting native or drought tolerant trees and shrubs in the landscape design.

The project shall reduce runoff volumes by directly connecting roof runoff to infiltration trenches located within the residential lot areas.

## IV.2 Source Control BMPs

### IV.2.1 Routine Non-Structural BMPs

**Table 2. Routine Non-Structural BMPs**

BMP No.	Name	Check One		If not applicable, state brief reason.
		Included	Not Applicable	
N1	Education for Property Owners, Tenants and Occupants	XX		
N2	Activity Restriction	XX		
N3	Common Area Landscape Management	XX		
N4	BMP Maintenance	XX		
N5	Title 22 CCR Compliance	XX		
N6	Local Water Quality Permit Compliance		X	The City/County of [redacted] does not issue water quality permits.
N7	Spill Contingency Plan		XX	Not applicable to this project
N8	Underground Storage Tank Compliance		XX	Not applicable to this project
N9	Hazardous Materials Disclosure Compliance	XX		
N10	Uniform Fire Code Implementation	XX		
N11	Common Area Litter Control	XX		
N12	Employee Training	XX		
N13	Housekeeping of Loading Docks		XX	Not applicable to this project
N14	Common Area Catch Basin Inspection	XX		
N15	Street Sweeping Private Streets and Parking Lots	XX		
N17**	Retail Gasoline Outlets		XX	Not applicable to this project

\*\* There is no BMP with the designation N16.

#### IV.2.1.1 Education of Property Owners/Tenants

The owner shall provide educational materials to tenants. Educational materials shall entail general housekeeping practices that contribute to the protection of stormwater quality and deleterious effects of household chemicals and waste, pesticides, fertilizers, and handling of pet waste. Educational materials will obtain brochures available from the County of Orange Stormwater Program website available at <http://www.ocwatersheds.com>.

The following are sample brochures that will be distributed and are located in Section VII of this WQMP.

- Recycle used oil
- Tips for Landscape & Gardening
- Tips for Home Improvement Projects
- Tips for Pool Maintenance
- Tips for Residential Pool, Landscape, and Hardscape drains
- Pet Care

#### **IV.2.1.2 Activity Restrictions**

The developer/builder homeowner shall restrict the use and handling of potential pollutants that could discharge into the storm drain system. Mitigation measures will include, but are not limited to, the following items: 1) Identification of key staff and/or subcontractors responsible or proper handling, use, and storage of pollutants; 2) Maintain employee records for training and new procedures; 3) Direct staff to report any unforeseen discharges to city/county officials. The home owner and landscaping maintenance personnel will oversee the following activity restrictions:

- Prohibit hosing down any paved surfaces including the driveways where the result would be the flow of non-stormwater into the streets or storm drains
- Prohibit dumping of any waste into catch basins.
- Prohibit of blowing or sweeping debris (leaf litter, grass clippings, litter, etc.) into catch basins and/or streets.
- Prohibit discharges of fertilizer or pesticides to streets or storm drains.
- Prohibit vehicle washing, maintenance, or repair on the premises.
- Pesticide application in common areas must be performed by an applicator certified by the California Department of Pesticide Regulation.

#### **IV.2.1.3 Employee Training / Education Program**

The home owner and Home Owners Association (HOA) will direct formal and informal training sessions to contracted landscape and maintenance staff regarding general housekeeping practices that contribute to the protection of stormwater quality, BMPs, stormwater discharge prohibitions, wastewater discharge requirements, proper spill containment, and clean-up. Initial training will be conducted during orientation and a follow-up annually thereafter. Training will involve review of videos and materials through various resources such as the County of Orange program website available at <http://www.ocwatersheds.com> and the State Water Resource Control Board website

available\_at <http://www.swrcb.ca.gov.stormwtr/training.html>. Informal on-site field reviews will be conducted to identify site-specific stormwater issues and BMP locations and follow up with inspections, reporting, and maintenance.

#### **IV.2.1.4 Common Area Catch Basin Inspection**

Drainage facilities (inlets, open channels and basins) must be inspected annually, in the late summer or early fall, and cleaned as needed, or if accumulated sediment/debris fills 25% or more of the sediment/debris storage capacity of the basin. The party responsible for post-construction operation and maintenance of drainage facilities shall evaluate all portions of the drainage facilities annually to determine the adequacy of the inspection and maintenance frequency, and report the evaluation findings to the HOA.

#### **IV.2.1.5 Street Sweeping Private Streets**

The HOA will provide street sweeping to private streets at least once a quarter, to reduce the amount of sediment, garden waste, and trash entering the storm drain systems.

#### IV.3 Routine Structural BMPs

**Table 3. Routine Structural BMPs**

Name	Check One		If not applicable, state brief reason
	Included	Not Applicable	
Provide storm drain system stenciling and signage	XX		
Design and construct outdoor material storage areas to reduce pollution introduction	XX		
Design and construct trash and waste storage areas to reduce pollution introduction	XX		
Use efficient irrigation systems & landscape design	XX		
Protect slopes and channels and provide energy dissipation	XX		
Incorporate requirements applicable to individual project features			
a. Dock areas		XX	Not applicable to this project
b. Maintenance bays		XX	Not applicable to this project
c. Vehicle wash areas		XX	Not applicable to this project
d. Outdoor processing areas		XX	Not applicable to this project
e. Equipment wash areas		XX	Not applicable to this project
f. Fueling areas		XX	Not applicable to this project
g. Hillside landscaping	XX		
h. Wash water control for food preparation areas		XX	Not applicable to this project
i. Community car wash racks		XX	Not applicable to this project

##### **IV.3.1.1 Storm Drain Stenciling and Signage (SD-13)**

Stenciling or labeling of all catch basins within the Project shall be "No Dumping, Flows to Creek" to discourage illegal dumping. The HOA will be responsible for maintenance.

##### **IV.3.1.2 Efficient Irrigation (SD-12)**

Project will implement efficient irrigation systems for landscape areas. Irrigation shall minimize runoff of excess irrigation water across impervious surfaces and into the storm water conveyance system. Measures will include employing rain-triggered shutoff devices to eliminate or reduce irrigation during and immediately after precipitation, using mulches (such as wood chips) to minimize sediment in runoff and to maintain soil infiltration capacity and coordinating design of the irrigation system to minimize overspray and runoff. Irrigation systems will consider the use of flow reducers or shutoff valves triggered by a pressure drop to control water loss in the event of broken heads or water supply lines.

#### **IV.3.1.3 Landscape Planning (SD-10)**

Landscaping will be located along the periphery of the site and throughout the parking lot. These will be site design landscape strips for pretreatment of storm runoff, before it enters the onsite storm drain system. Landscaping will include drought tolerant plantings resulting in water conservation. Plantings will be grouped with similar water requirements in order to reduce excess irrigation runoff and promote surface filtration opportunities. Landscaping will correlate to the climate, soil, related natural resources and existing vegetation of the project area. Ongoing maintenance will be consistent with County Administrative Guidelines or local equivalent, plus fertilizer and pesticide use consistent with the instructions contained on product labels and with the regulations administered by the State Department of Pesticide Regulation shall be implemented. All landscape areas will have a three (3) inch freeboard to prevent routine irrigation overflow, therefore reducing the possibility of nutrients and pesticides from entering the public storm drain system. Additional information describing these practices is available in BMP Fact Sheets located in Attachment B.

#### **IV.3.1.4 Roof Runoff Controls (SD-11)**

Roof-runoff shall be directed into landscape areas for filtration and infiltration, as applicable.

#### IV.4 Treatment Control BMPs

**Table 4. Treatment Control BMPs**

Name	Included?	
	Yes	No
Vegetated (Grass) Strips	XX	
Vegetated (Grass) Swales	XX	
Dry Detention Basin		XX
Wet Detention Basin		XX
Constructed Wetland		XX
Detention Basin/Sand Filter		XX
Porous Pavement Detention	XX	
Porous Landscape Detention	XX	
Infiltration Basin		XX
Infiltration Trench	XX	
Media Filter		XX
Proprietary Control Measures		XX

##### **IV.4.1.1 Vegetated Swales (TC-30)**

Vegetated swales should be used along roadside ditches whenever street grade rates are determined to be feasible.

##### **IV.4.1.2 Vegetated Buffer Strips (TC-31)**

Vegetated buffer strips should be used along roadside shoulders and residential lot boundaries when slope and length meet criteria and are determined to be feasible.

##### **IV.4.1.3 Porous Pavement Detention**

The use of porous pavement for hardscape areas (driveways, walkways, patios, etc.) within the residential lots shall be considered.

##### **IV.4.1.3 Porous Landscape Detention**

The use of porous landscape areas within residential lots in conjunction with infiltration trenches shall be considered.

**IV.4.1.3 Infiltration Trench (TC-10)**

The use of infiltration trenches within residential lots shall be required where feasible.

## **V. Implementation, Maintenance and Inspection Responsibility for BMPs (O&M Plan)**

### **V.1 Operations and Maintenance**

The Owner shall be responsible for all BMPs (Site Design, Source Control, And Treatment Control). Table 5, BMP Operations and Maintenance, further describes BMP implementation including special handling and placement of any wastes, BMP start-up dates, and a schedule of the frequency of O&M for each BMP. In addition, the Owner will comply with the County's maintenance policy.

### **V.2 Inspection and Monitoring Requirements**

The Owner will employ self-inspections and record keeping for BMPs, as applicable. The Owner shall retain all maintenance records for a period of three (3) years after the recorded inspection date for the lifetime of the Project. The records shall be made readily available for review by all government agencies. Depending on the type of BMP, minimum frequency of inspections may range from weekly, to once a month, quarterly, or yearly. Table 5, BMP Operation and Maintenance, further identifies schedule for inspections.

### **V.3 Responsible Party(ies)**

The Owner shall be responsible for management/implementation of all other BMPs with the following contact information of the persons(s) responsible for inspecting and maintaining each BMP during operating hours:

Contact Name:

Title: Owner's Representative  
Address: 22861 Tindaya, Mission Viejo, CA 93692  
Phone: (949) 830-3444

Responsibilities include, but are not limited to, the following activities:

- ✓ Ensuring full compliance with stormwater regulations
- ✓ Implementing all non-stormwater management and materials, and waste management activities such as: monitoring discharges, general clean-up, vehicle and equipment cleaning, spill control; ensuring that no materials other than stormwater are discharged in quantities which will have an adverse effect on receiving waters or storm drain systems, etc.
- ✓ Pre and post-storm event inspections
- ✓ Routine Inspections

- ✓ Coordinate and assure all of the necessary corrections/repairs are made immediately
- ✓ Submitting Notices of Discharge and reports of Illicit Connections or Illegal Discharges

#### **V.4 Transfer of Ownership**

Should a transfer of ownership occur, appropriate notification will be filed with the County of Orange confirming the change in responsibility and continued implementation of stormwater management requirements.

# Preliminary WQMP for

Coto De Caza Estates  
Tentative Tract 17325

**Table 5**  
**BMP Operations & Maintenance**

BMP Description	Maintenance Responsibility	Funding Source For O & M	Maintenance Schedule
<p><b>1. Education of Property Owners/Tenants</b> The developer will provide initial environmental awareness education materials upon transfer of ownership to each property owner during walk-through inspection. Educational materials shall entail general housekeeping practices that contribute to the protection of stormwater quality and the deleterious effects of household chemicals and waste pesticides, fertilizers, and handling of pet waste. Educational materials will obtain brochures available from the County of Orange website available at <a href="http://www.ocwatersheds.com">http://www.ocwatersheds.com</a></p> <p><b>2. Activity Restrictions</b> The homeowner will restrict the use and handling potential pollutants that could discharge into the storm drain system. Mitigation measures will include, but are not limited to, the following items: 1) Identification of key staff and/or subcontractors responsible for proper handling, use, and storage of pollutants; 2) Maintain employee records for training and new procedures; 3) Direct staff to report any unforeseen discharges to County officials. Landscaping maintenance personnel will oversee the following activity restrictions:</p> <ul style="list-style-type: none"> <li>Prohibit hosing down any paved surfaces including the parking lot where the result would be the flow of non-stormwater into the streets or storm drains</li> <li>Prohibit dumping of any waste into catch basins.</li> <li>Prohibit blowing or sweeping debris (leaf litter, grass clippings, litter, etc.) into catch basins and/or streets.</li> <li>Prohibit discharges of fertilizer or pesticides to streets or storm drains.</li> <li>Prohibit vehicle washing, maintenance, or repair on the premises.</li> <li>Pesticide application in common areas must be performed by an applicator certified by the California Department of Pesticide Regulation.</li> </ul>	Owner	Owner	Annually
	Owner	Owner	Varies by BMP

# Preliminary WQMP for

Coto De Caza Estates  
Tentative Tract 17325

**Table 5**  
**BMP Operations & Maintenance**

	Owner	Owner	Annually
<p><b>3. Employee Training / Education Program</b></p> <p>The owner will direct formal and informal training sessions to contracted landscape and maintenance staff regarding general housekeeping practices that contribute to the protection of stormwater quality. BMPs, stormwater discharge prohibitions, wastewater discharge requirements, proper spill containment, and clean-up. Initial training will be conducted during orientation and a follow-up annually thereafter. Training will involve review of videos and materials through various resources such as the County of Orange Program website available at <a href="http://www.ocwatersheds.com">http://www.ocwatersheds.com</a> and the State Water Resource Control Board website available at <a href="http://www.swrcb.ca.gov/stormwtr/training.html">http://www.swrcb.ca.gov/stormwtr/training.html</a>. Informal on-site field reviews will be conducted to identify site-specific stormwater issues and BMP locations and follow up with inspections, reporting, and maintenance.</p>	HOA	HOA	Annually
<p><b>4. Common Area Catch Basin Inspection</b></p> <p>Drainage facilities (inlets, open channels and basins) must be inspected annually, in the late summer or early fall, and cleaned as needed, or if accumulated sediment/debris fills 25% or more of the sediment/debris storage capacity of the basin. The party responsible for post-construction operation and maintenance of drainage facilities shall evaluate all portions of the drainage facilities annually to determine the adequacy of the inspection and maintenance frequency, and report the evaluation findings to the owner.</p>	HOA	HOA	Annually including once prior to rainy season (October 1)
<p><b>5. Street Sweeping Private Streets</b></p> <p>The HOA will provide street sweeping to private streets at least once a quarter, to reduce the amount of sediment, garden waste, and trash entering the storm drain systems.</p>	HOA	HOA	Quarterly, including once prior to rainy season (October 1)
<p><b>6. Storm Drain Stenciling and Signage (SD-13)</b></p> <p>The Property Owner shall be responsible for maintenance of stencil or affix signs that contain a brief statement that prohibits dumping of materials into urban runoff conveyance systems. The markers or placards should be placed in sight facing towards anyone approaching the inlet from either side. The following will be in the project design and show on project plans: Provide stenciling or labeling of all storm drain inlets and catch basins; constructed or modified, within the project area with prohibitive language per City of Fontana standards. Inspections shall be conducted annually to confirm legibility of signage. Repair and repainting shall be conducted, as needed.</p>	Owner	Owner	Annually
<p><b>7. Efficient Irrigation (SD-12)</b></p> <p>Project will implement efficient irrigation systems for landscape areas. Irrigation shall minimize runoff of excess irrigation water across impervious surfaces and into the storm water</p>	Owner	Owner	Quarterly and adjust accordingly based on seasonal changes.

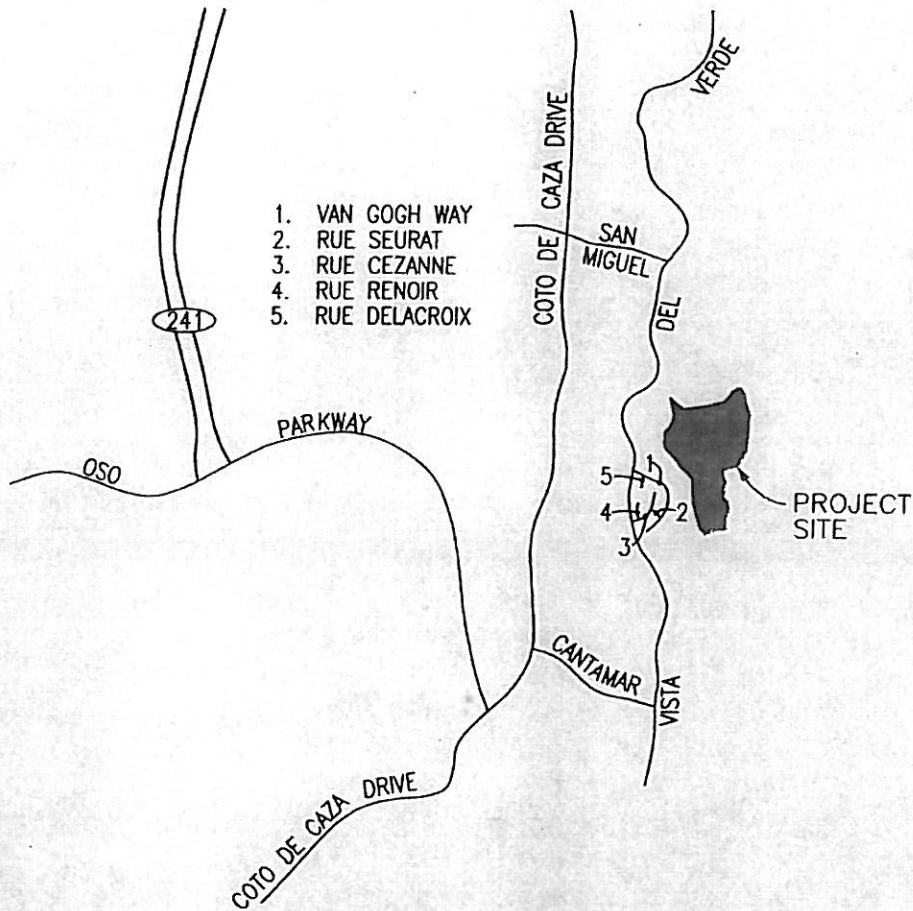
# Preliminary WQMP for

Coto De Caza Estates  
Tentative Tract 17325

conveyance system. Measures will include employing rain-triggered shutoff devices to eliminate or reduce irrigation during and immediately after precipitation, using mulches (such as wood chips) to minimize sediment in runoff and to maintain soil infiltration capacity and coordinating design of the irrigation system to minimize overspray and runoff. Irrigation systems will consider the use of flow reducers or shutoff valves triggered by a pressure drop to control water loss in the event of broken heads or water supply lines.			
Table 5 BMP Operations & Maintenance			
8. <u>Landscape Planning (SD-10)</u> Landscaping will be located within residential lots and along private streets.. These will be site design landscape strips for pretreatment of storm runoff, before it enters the onsite storm drain system. Landscaping will include drought tolerant plantings resulting in water conservation. Plantings will be grouped with similar water requirements in order to reduce excess irrigation runoff and promote surface filtration opportunities. Landscaping will correlate to the climate, soil, related natural resources and existing vegetation of the project area. Ongoing maintenance will be consistent with County Administrative Guidelines available at <a href="http://www.ocwatersheds.com">http://www.ocwatersheds.com</a> or local equivalent, plus fertilizer and pesticide use consistent with the instructions contained on product labels and with the regulations administered by the State Department of Pesticide Regulation shall be implemented. All landscape areas will have a three (3) inch freeboard to prevent routine irrigation overflow, therefore reducing the possibility of nutrients and pesticides from entering the public storm drain system.	Prior to Operations	Owner	Owner
9. <u>Roof Runoff Controls (SD-11)</u> Roof-runoff shall be directed into landscape areas for filtration and infiltration, as applicable.	Owner	Owner	Annually including once prior to rainy season (October 1)
10. <u>Vegetated Swales (TC-30)</u> Infiltration trenches shall be incorporated into residential lot design where feasible.	Owner	Owner	Semi-annually
11. <u>Vegetated Buffer Strips (TC-31)</u> Infiltration trenches shall be incorporated into residential lot design where feasible.	Owner	Owner	Semi-annually
12. <u>Infiltration Trenches (TC-10)</u> Infiltration trenches shall be incorporated into residential lot design where feasible.	Owner	Owner	Semi-annually

**VI. Location Map, Site Plan, and BMP Details**

## LOCATION MAP



## VICINITY MAP

NOT TO SCALE

SECTION 2, TOWNSHIP 7 SOUTH,  
RANGE 7 WEST  
THOMAS BROS., 2007 ED.,  
PG. 923, GRID D-3

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Site MAP

# Site Design & Landscape Planning SD-10



## Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Slow Runoff
- ✓ Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- Contain Pollutants
- Collect and Convey

## Description

Each project site possesses unique topographic, hydrologic, and vegetative features, some of which are more suitable for development than others. Integrating and incorporating appropriate landscape planning methodologies into the project design is the most effective action that can be done to minimize surface and groundwater contamination from stormwater.

## Approach

Landscape planning should couple consideration of land suitability for urban uses with consideration of community goals and projected growth. Project plan designs should conserve natural areas to the extent possible, maximize natural water storage and infiltration opportunities, and protect slopes and channels.

## Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment.

## Design Considerations

Design requirements for site design and landscapes planning should conform to applicable standards and specifications of agencies with jurisdiction and be consistent with applicable General Plan and Local Area Plan policies.



# **SD-10 Site Design & Landscape Planning**

## ***Designing New Installations***

Begin the development of a plan for the landscape unit with attention to the following general principles:

- Formulate the plan on the basis of clearly articulated community goals. Carefully identify conflicts and choices between retaining and protecting desired resources and community growth.
- Map and assess land suitability for urban uses. Include the following landscape features in the assessment: wooded land, open unwooded land, steep slopes, erosion-prone soils, foundation suitability, soil suitability for waste disposal, aquifers, aquifer recharge areas, wetlands, floodplains, surface waters, agricultural lands, and various categories of urban land use. When appropriate, the assessment can highlight outstanding local or regional resources that the community determines should be protected (e.g., a scenic area, recreational area, threatened species habitat, farmland, fish run). Mapping and assessment should recognize not only these resources but also additional areas needed for their sustenance.

Project plan designs should conserve natural areas to the extent possible, maximize natural water storage and infiltration opportunities, and protect slopes and channels.

## ***Conserve Natural Areas during Landscape Planning***

If applicable, the following items are required and must be implemented in the site layout during the subdivision design and approval process, consistent with applicable General Plan and Local Area Plan policies:

- Cluster development on least-sensitive portions of a site while leaving the remaining land in a natural undisturbed condition.
- Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.
- Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought tolerant plants.
- Promote natural vegetation by using parking lot islands and other landscaped areas.
- Preserve riparian areas and wetlands.

## ***Maximize Natural Water Storage and Infiltration Opportunities Within the Landscape Unit***

- Promote the conservation of forest cover. Building on land that is already deforested affects basin hydrology to a lesser extent than converting forested land. Loss of forest cover reduces interception storage, detention in the organic forest floor layer, and water losses by evapotranspiration, resulting in large peak runoff increases and either their negative effects or the expense of countering them with structural solutions.
- Maintain natural storage reservoirs and drainage corridors, including depressions, areas of permeable soils, swales, and intermittent streams. Develop and implement policies and

# Site Design & Landscape Planning SD-10

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regulations to discourage the clearing, filling, and channelization of these features. Utilize them in drainage networks in preference to pipes, culverts, and engineered ditches.

- Evaluating infiltration opportunities by referring to the stormwater management manual for the jurisdiction and pay particular attention to the selection criteria for avoiding groundwater contamination, poor soils, and hydrogeological conditions that cause these facilities to fail. If necessary, locate developments with large amounts of impervious surfaces or a potential to produce relatively contaminated runoff away from groundwater recharge areas.

## *Protection of Slopes and Channels during Landscape Design*

- Convey runoff safely from the tops of slopes.
- Avoid disturbing steep or unstable slopes.
- Avoid disturbing natural channels.
- Stabilize disturbed slopes as quickly as possible.
- Vegetate slopes with native or drought tolerant vegetation.
- Control and treat flows in landscaping and/or other controls prior to reaching existing natural drainage systems.
- Stabilize temporary and permanent channel crossings as quickly as possible, and ensure that increases in run-off velocity and frequency caused by the project do not erode the channel.
- Install energy dissipaters, such as riprap, at the outlets of new storm drains, culverts, conduits, or channels that enter unlined channels in accordance with applicable specifications to minimize erosion. Energy dissipaters shall be installed in such a way as to minimize impacts to receiving waters.
- Line on-site conveyance channels where appropriate, to reduce erosion caused by increased flow velocity due to increases in tributary impervious area. The first choice for linings should be grass or some other vegetative surface, since these materials not only reduce runoff velocities, but also provide water quality benefits from filtration and infiltration. If velocities in the channel are high enough to erode grass or other vegetative linings, riprap, concrete, soil cement, or geo-grid stabilization are other alternatives.
- Consider other design principles that are comparable and equally effective.

## ***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define “redevelopment” in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of “redevelopment” must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under “designing new installations” above should be followed.

## **SD-10 Site Design & Landscape Planning**

Redevelopment may present significant opportunity to add features which had not previously been implemented. Examples include incorporation of depressions, areas of permeable soils, and swales in newly redeveloped areas. While some site constraints may exist due to the status of already existing infrastructure, opportunities should not be missed to maximize infiltration, slow runoff, reduce impervious areas, disconnect directly connected impervious areas.

### **Other Resources**

A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.

Stormwater Management Manual for Western Washington, Washington State Department of Ecology, August 2001.

Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, February 14, 2002.

Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, Draft February 2003.

Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, July 2002.



Rain Garden

### Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Slow Runoff
- Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- ✓ Contain Pollutants
- Collect and Convey

### Description

Various roof runoff controls are available to address stormwater that drains off rooftops. The objective is to reduce the total volume and rate of runoff from individual lots, and retain the pollutants on site that may be picked up from roofing materials and atmospheric deposition. Roof runoff controls consist of directing the roof runoff away from paved areas and mitigating flow to the storm drain system through one of several general approaches: cisterns or rain barrels; dry wells or infiltration trenches; pop-up emitters, and foundation planting. The first three approaches require the roof runoff to be contained in a gutter and downspout system. Foundation planting provides a vegetated strip under the drip line of the roof.

### Approach

Design of individual lots for single-family homes as well as lots for higher density residential and commercial structures should consider site design provisions for containing and infiltrating roof runoff or directing roof runoff to vegetative swales or buffer areas. Retained water can be reused for watering gardens, lawns, and trees. Benefits to the environment include reduced demand for potable water used for irrigation, improved stormwater quality, increased groundwater recharge, decreased runoff volume and peak flows, and decreased flooding potential.

### Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment.

### Design Considerations

#### *Designing New Installations*

##### *Cisterns or Rain Barrels*

One method of addressing roof runoff is to direct roof downspouts to cisterns or rain barrels. A cistern is an above ground storage vessel with either a manually operated valve or a permanently open outlet. Roof runoff is temporarily stored and then released for irrigation or infiltration between storms. The number of rain



barrels needed is a function of the rooftop area. Some low impact developers recommend that every house have at least 2 rain barrels, with a minimum storage capacity of 1000 liters. Roof barrels serve several purposes including mitigating the first flush from the roof which has a high volume, amount of contaminants, and thermal load. Several types of rain barrels are commercially available. Consideration must be given to selecting rain barrels that are vector proof and childproof. In addition, some barrels are designed with a bypass valve that filters out grit and other contaminants and routes overflow to a soak-away pit or rain garden.

If the cistern has an operable valve, the valve can be closed to store stormwater for irrigation or infiltration between storms. This system requires continual monitoring by the resident or grounds crews, but provides greater flexibility in water storage and metering. If a cistern is provided with an operable valve and water is stored inside for long periods, the cistern must be covered to prevent mosquitoes from breeding.

A cistern system with a permanently open outlet can also provide for metering stormwater runoff. If the cistern outlet is significantly smaller than the size of the downspout inlet (say  $\frac{1}{4}$  to  $\frac{1}{2}$  inch diameter), runoff will build up inside the cistern during storms, and will empty out slowly after peak intensities subside. This is a feasible way to mitigate the peak flow increases caused by rooftop impervious land coverage, especially for the frequent, small storms.

#### *Dry wells and Infiltration Trenches*

Roof downspouts can be directed to dry wells or infiltration trenches. A dry well is constructed by excavating a hole in the ground and filling it with an open graded aggregate, and allowing the water to fill the dry well and infiltrate after the storm event. An underground connection from the downspout conveys water into the dry well, allowing it to be stored in the voids. To minimize sedimentation from lateral soil movement, the sides and top of the stone storage matrix can be wrapped in a permeable filter fabric, though the bottom may remain open. A perforated observation pipe can be inserted vertically into the dry well to allow for inspection and maintenance.

In practice, dry wells receiving runoff from single roof downspouts have been successful over long periods because they contain very little sediment. They must be sized according to the amount of rooftop runoff received, but are typically 4 to 5 feet square, and 2 to 3 feet deep, with a minimum of 1-foot soil cover over the top (maximum depth of 10 feet).

To protect the foundation, dry wells must be set away from the building at least 10 feet. They must be installed in solids that accommodate infiltration. In poorly drained soils, dry wells have very limited feasibility.

Infiltration trenches function in a similar manner and would be particularly effective for larger roof areas. An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff. These are described under Treatment Controls.

#### *Pop-up Drainage Emitter*

Roof downspouts can be directed to an underground pipe that daylights some distance from the building foundation, releasing the roof runoff through a pop-up emitter. Similar to a pop-up irrigation head, the emitter only opens when there is flow from the roof. The emitter remains flush to the ground during dry periods, for ease of lawn or landscape maintenance.

## *Foundation Planting*

Landscape planting can be provided around the base to allow increased opportunities for stormwater infiltration and protect the soil from erosion caused by concentrated sheet flow coming off the roof. Foundation plantings can reduce the physical impact of water on the soil and provide a subsurface matrix of roots that encourage infiltration. These plantings must be sturdy enough to tolerate the heavy runoff sheet flows, and periodic soil saturation.

## ***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define “redevelopment” in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of “redevelopment” must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under “designing new installations” above should be followed.

## **Supplemental Information**

### ***Examples***

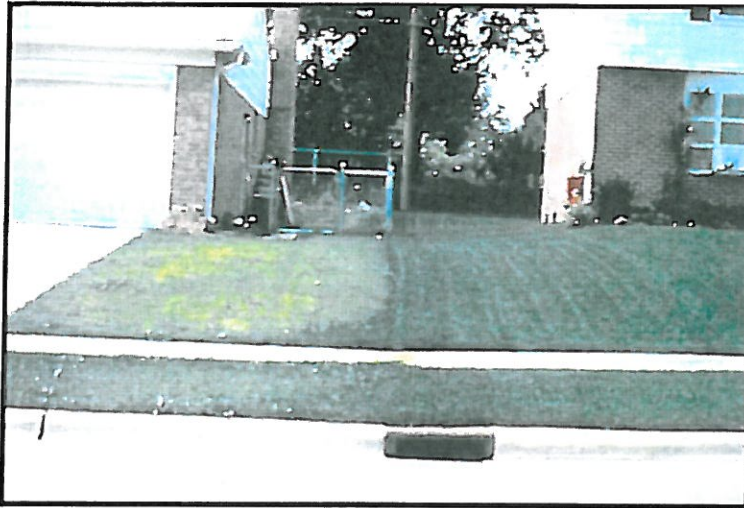
- City of Ottawa’s Water Links Surface –Water Quality Protection Program
- City of Toronto Downspout Disconnection Program
- City of Boston, MA, Rain Barrel Demonstration Program

### **Other Resources**

Hager, Marty Catherine, Stormwater, “Low-Impact Development”, January/February 2003.  
[www.stormh2o.com](http://www.stormh2o.com)

Low Impact Urban Design Tools, Low Impact Development Design Center, Beltsville, MD.  
[www.lid-stormwater.net](http://www.lid-stormwater.net)

Start at the Source, Bay Area Stormwater Management Agencies Association, 1999 Edition



### Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
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### Description

Irrigation water provided to landscaped areas may result in excess irrigation water being conveyed into stormwater drainage systems.

### Approach

Project plan designs for development and redevelopment should include application methods of irrigation water that minimize runoff of excess irrigation water into the stormwater conveyance system.

### Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment. (Detached residential single-family homes are typically excluded from this requirement.)

### Design Considerations

#### *Designing New Installations*

The following methods to reduce excessive irrigation runoff should be considered, and incorporated and implemented where determined applicable and feasible by the Permittee:

- Employ rain-triggered shutoff devices to prevent irrigation after precipitation.
- Design irrigation systems to each landscape area's specific water requirements.
- Include design featuring flow reducers or shutoff valves triggered by a pressure drop to control water loss in the event of broken sprinkler heads or lines.
- Implement landscape plans consistent with County or City water conservation resolutions, which may include provision of water sensors, programmable irrigation times (for short cycles), etc.



- Design timing and application methods of irrigation water to minimize the runoff of excess irrigation water into the storm water drainage system.
- Group plants with similar water requirements in order to reduce excess irrigation runoff and promote surface filtration. Choose plants with low irrigation requirements (for example, native or drought tolerant species). Consider design features such as:
  - Using mulches (such as wood chips or bar) in planter areas without ground cover to minimize sediment in runoff
  - Installing appropriate plant materials for the location, in accordance with amount of sunlight and climate, and use native plant materials where possible and/or as recommended by the landscape architect
  - Leaving a vegetative barrier along the property boundary and interior watercourses, to act as a pollutant filter, where appropriate and feasible
  - Choosing plants that minimize or eliminate the use of fertilizer or pesticides to sustain growth
- Employ other comparable, equally effective methods to reduce irrigation water runoff.

***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define "redevelopment" in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of "redevelopment" must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under "designing new installations" above should be followed.

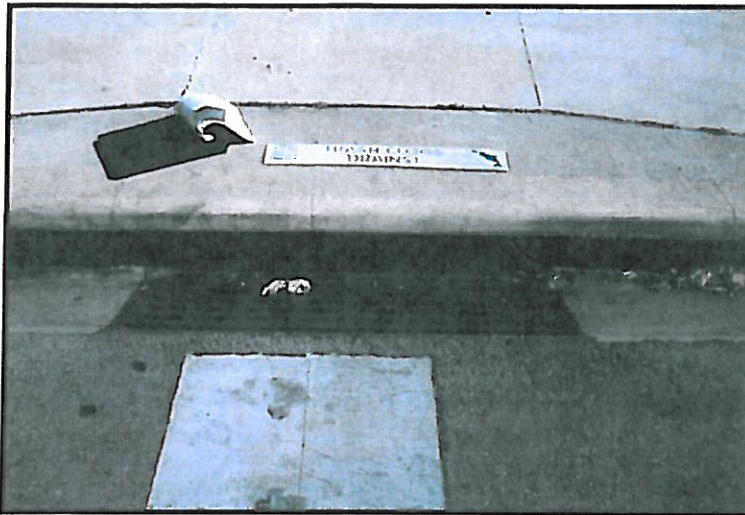
**Other Resources**

A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.

Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, February 14, 2002.

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### Design Objectives

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### Description

Waste materials dumped into storm drain inlets can have severe impacts on receiving and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can prevent waste dumping. Storm drain signs and stencils are highly visible source controls that are typically placed directly adjacent to storm drain inlets.

### Approach

The stencil or affixed sign contains a brief statement that prohibits dumping of improper materials into the urban runoff conveyance system. Storm drain messages have become a popular method of alerting the public about the effects of and the prohibitions against waste disposal.

### Suitable Applications

Stencils and signs alert the public to the destination of pollutants discharged to the storm drain. Signs are appropriate in residential, commercial, and industrial areas, as well as any other area where contributions or dumping to storm drains is likely.

### Design Considerations

Storm drain message markers or placards are recommended at all storm drain inlets within the boundary of a development project. The marker should be placed in clear sight facing toward anyone approaching the inlet from either side. All storm drain inlet locations should be identified on the development site map.

### Designing New Installations

The following methods should be considered for inclusion in the project design and show on project plans:

- Provide stenciling or labeling of all storm drain inlets and catch basins, constructed or modified, within the project area with prohibitive language. Examples include "NO DUMPING –



DRAINS TO OCEAN” and/or other graphical icons to discourage illegal dumping.

- Post signs with prohibitive language and/or graphical icons, which prohibit illegal dumping at public access points along channels and creeks within the project area.

Note - Some local agencies have approved specific signage and/or storm drain message placards for use. Consult local agency stormwater staff to determine specific requirements for placard types and methods of application.

### ***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define “redevelopment” in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. If the project meets the definition of “redevelopment”, then the requirements stated under “designing new installations” above should be included in all project design plans.

### **Additional Information**

#### ***Maintenance Considerations***

- Legibility of markers and signs should be maintained. If required by the agency with jurisdiction over the project, the owner/operator or homeowner’s association should enter into a maintenance agreement with the agency or record a deed restriction upon the property title to maintain the legibility of placards or signs.

#### ***Placement***

- Signage on top of curbs tends to weather and fade.
- Signage on face of curbs tends to be worn by contact with vehicle tires and sweeper brooms.

### **Supplemental Information**

#### ***Examples***

- Most MS4 programs have storm drain signage programs. Some MS4 programs will provide stencils, or arrange for volunteers to stencil storm drains as part of their outreach program.

### **Other Resources**

A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.

Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, February 14, 2002.

Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, Draft February 2003.

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## Description

Pervious paving is used for light vehicle loading in parking areas. The term describes a system comprising a load-bearing, durable surface together with an underlying layered structure that temporarily stores water prior to infiltration or drainage to a controlled outlet. The surface can itself be porous such that water infiltrates across the entire surface of the material (e.g., grass and gravel surfaces, porous concrete and porous asphalt), or can be built up of impermeable blocks separated by spaces and joints, through which the water can drain. This latter system is termed 'permeable' paving. Advantages of pervious pavements is that they reduce runoff volume while providing treatment, and are unobtrusive resulting in a high level of acceptability.

## Approach

Attenuation of flow is provided by the storage within the underlying structure or sub base, together with appropriate flow controls. An underlying geotextile may permit groundwater recharge, thus contributing to the restoration of the natural water cycle. Alternatively, where infiltration is inappropriate (e.g., if the groundwater vulnerability is high, or the soil type is unsuitable), the surface can be constructed above an impermeable membrane. The system offers a valuable solution for drainage of spatially constrained urban areas.

Significant attenuation and improvement in water quality can be achieved by permeable pavements, whichever method is used. The surface and subsurface infrastructure can remove both the soluble and fine particulate pollutants that occur within urban runoff. Roof water can be piped into the storage area directly, adding areas from which the flow can be attenuated. Also, within lined systems, there is the opportunity for stored runoff to be piped out for reuse.

## Suitable Applications

Residential, commercial and industrial applications are possible. The use of permeable pavement may be restricted in cold regions, arid regions or regions with high wind erosion. There are some specific disadvantages associated with permeable pavement, which are as follows:

- Permeable pavement can become clogged if improperly installed or maintained. However, this is countered by the ease with which small areas of paving can be cleaned or replaced when blocked or damaged.

- Their application should be limited to highways with low traffic volumes, axle loads and speeds (less than 30 mph limit), car parking areas and other lightly trafficked or non-trafficked areas. Permeable surfaces are currently not considered suitable for adoptable roads due to the risks associated with failure on high speed roads, the safety implications of ponding, and disruption arising from reconstruction.
- When using un-lined, infiltration systems, there is some risk of contaminating groundwater, depending on soil conditions and aquifer susceptibility. However, this risk is likely to be small because the areas drained tend to have inherently low pollutant loadings.
- The use of permeable pavement is restricted to gentle slopes.
- Porous block paving has a higher risk of abrasion and damage than solid blocks.

**Design Considerations*****Designing New Installations***

If the grades, subsoils, drainage characteristics, and groundwater conditions are suitable, permeable paving may be substituted for conventional pavement on parking areas, cul de sacs and other areas with light traffic. Slopes should be flat or very gentle. Scottish experience has shown that permeable paving systems can be installed in a wide range of ground conditions, and the flow attenuation performance is excellent even when the systems are lined.

The suitability of a pervious system at a particular pavement site will, however, depend on the loading criteria required of the pavement.

Where the system is to be used for infiltrating drainage waters into the ground, the vulnerability of local groundwater sources to pollution from the site should be low, and the seasonal high water table should be at least 4 feet below the surface.

Ideally, the pervious surface should be horizontal in order to intercept local rainfall at source. On sloping sites, pervious surfaces may be terraced to accommodate differences in levels.

***Design Guidelines***

The design of each layer of the pavement must be determined by the likely traffic loadings and their required operational life. To provide satisfactory performance, the following criteria should be considered:

- The subgrade should be able to sustain traffic loading without excessive deformation.
- The granular capping and sub-base layers should give sufficient load-bearing to provide an adequate construction platform and base for the overlying pavement layers.
- The pavement materials should not crack or suffer excessive rutting under the influence of traffic. This is controlled by the horizontal tensile stress at the base of these layers.

There is no current structural design method specifically for pervious pavements. Allowances should be considered the following factors in the design and specification of materials:

- Pervious pavements use materials with high permeability and void space. All the current UK pavement design methods are based on the use of conventional materials that are dense and relatively impermeable. The stiffness of the materials must therefore be assessed.
- Water is present within the construction and can soften and weaken materials, and this must be allowed for.
- Existing design methods assume full friction between layers. Any geotextiles or geomembranes must be carefully specified to minimize loss of friction between layers.
- Porous asphalt loses adhesion and becomes brittle as air passes through the voids. Its durability is therefore lower than conventional materials.

The single sized grading of materials used means that care should be taken to ensure that loss of finer particles between unbound layers does not occur.

Positioning a geotextile near the surface of the pervious construction should enable pollutants to be trapped and retained close to the surface of the construction. This has both advantages and disadvantages. The main disadvantage is that the filtering of sediments and their associated pollutants at this level may hamper percolation of waters and can eventually lead to surface ponding. One advantage is that even if eventual maintenance is required to reinstate infiltration, only a limited amount of the construction needs to be disturbed, since the sub-base below the geotextile is protected. In addition, the pollutant concentration at a high level in the structure allows for its release over time. It is slowly transported in the stormwater to lower levels where chemical and biological processes may be operating to retain or degrade pollutants.

The design should ensure that sufficient void space exists for the storage of sediments to limit the period between remedial works.

- Pervious pavements require a single size grading to give open voids. The choice of materials is therefore a compromise between stiffness, permeability and storage capacity.
- Because the sub-base and capping will be in contact with water for a large part of the time, the strength and durability of the aggregate particles when saturated and subjected to wetting and drying should be assessed.
- A uniformly graded single size material cannot be compacted and is liable to move when construction traffic passes over it. This effect can be reduced by the use of angular crushed rock material with a high surface friction.

In pollution control terms, these layers represent the site of long term chemical and biological pollutant retention and degradation processes. The construction materials should be selected, in addition to their structural strength properties, for their ability to sustain such processes. In general, this means that materials should create neutral or slightly alkaline conditions and they should provide favorable sites for colonization by microbial populations.

### *Construction/Inspection Considerations*

- Permeable surfaces can be laid without cross-falls or longitudinal gradients.
- The blocks should be laid level

- They should not be used for storage of site materials, unless the surface is well protected from deposition of silt and other spillages.
- The pavement should be constructed in a single operation, as one of the last items to be built, on a development site. Landscape development should be completed before pavement construction to avoid contamination by silt or soil from this source.
- Surfaces draining to the pavement should be stabilized before construction of the pavement.
- Inappropriate construction equipment should be kept away from the pavement to prevent damage to the surface, sub-base or sub-grade.

#### *Maintenance Requirements*

The maintenance requirements of a pervious surface should be reviewed at the time of design and should be clearly specified. Maintenance is required to prevent clogging of the pervious surface. The factors to be considered when defining maintenance requirements must include:

- Type of use
- Ownership
- Level of trafficking
- The local environment and any contributing catchments

Studies in the UK have shown satisfactory operation of porous pavement systems without maintenance for over 10 years and recent work by Imbe et al. at 9th ICUD, Portland, 2002 describes systems operating for over 20 years without maintenance. However, performance under such regimes could not be guaranteed, Table 1 shows typical recommended maintenance regimes:

Table 1 Typical Recommended Maintenance Regimes	
Activity	Schedule
<ul style="list-style-type: none"> <li>Minimize use of salt or grit for de-icing</li> <li>Keep landscaped areas well maintained</li> <li>Prevent soil being washed onto pavement</li> </ul>	Ongoing
<ul style="list-style-type: none"> <li>Vacuum clean surface using commercially available sweeping machines at the following times:                             <ul style="list-style-type: none"> <li>End of winter (April)</li> <li>Mid-summer (July / August)</li> <li>After Autumn leaf-fall (November)</li> </ul> </li> </ul>	2/3 x per year
<ul style="list-style-type: none"> <li>Inspect outlets</li> </ul>	Annual
<ul style="list-style-type: none"> <li>If routine cleaning does not restore infiltration rates, then reconstruction of part of the whole of a pervious surface may be required.</li> <li>The surface area affected by hydraulic failure should be lifted for inspection of the internal materials to identify the location and extent of the blockage.</li> <li>Surface materials should be lifted and replaced after brush cleaning. Geotextiles may need complete replacement.</li> <li>Sub-surface layers may need cleaning and replacing.</li> <li>Removed silts may need to be disposed of as controlled waste.</li> </ul>	As needed (infrequent) Maximum 15-20 years

Permeable pavements are up to 25 % cheaper (or at least no more expensive than the traditional forms of pavement construction), when all construction and drainage costs are taken into account. (Accepting that the porous asphalt itself is a more expensive surfacing, the extra cost of which is offset by the savings in underground pipework etc.) (Niernczynowicz, et al., 1987)

Table 1 gives US cost estimates for capital and maintenance costs of porous pavements (Landphair et al., 2000)

## ***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define "redevelopment" in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of "redevelopment" must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under "designing new installations" above should be followed.

**Additional Information***Cost Considerations*

Permeable pavements are up to 25 % cheaper (or at least no more expensive than the traditional forms of pavement construction), when all construction and drainage costs are taken into account. (Accepting that the porous asphalt itself is a more expensive surfacing, the extra cost of which is offset by the savings in underground pipework etc.) (Niemczynowicz, et al., 1987)

Table 2 gives US cost estimates for capital and maintenance costs of porous pavements (Landphair et al., 2000)

Table 2 Engineer's Estimate for Porous Pavement

Porous Pavement													
Item	Units	Price	Cycles/Year	Quant. 1 Acres WS	Total	Quant. 2 Acres WS	Total	Quant. 3 Acres WS	Total	Quant. 4 Acres WS	Total	Quant. 5 Acres WS	Total
Grading	SY	\$2.00		604	\$1,208	1209	\$2,418	1812	\$3,624	2419	\$4,838	3020	\$6,040
Paving	SY	\$19.00		212	\$4,028	424	\$8,056	636	\$12,084	848	\$16,112	1060	\$20,140
Excavation	CY	\$3.60		201	\$724	403	\$1,451	604	\$2,174	806	\$2,902	1008	\$3,628
Filter Fabric	SY	\$1.15		700	\$805	1400	\$1,610	2000	\$2,300	2800	\$3,220	3600	\$4,140
Stone Fill	CY	\$16.00		201	\$3,216	403	\$6,448	604	\$9,664	806	\$12,896	1008	\$16,128
Sand	CY	\$7.00		100	\$700	200	\$1,400	300	\$2,100	400	\$2,800	500	\$3,500
Sight Wall	EA	\$300.00		2	\$600	3	\$900	4	\$1,200	7	\$2,100	7	\$2,100
Seeding	LF	\$0.05		644	\$32	1288	\$64	1932	\$97	2576	\$129	3220	\$161
Check Dam	CY	\$35.00		0	\$0	0	\$0	0	\$0	0	\$0	0	\$0
Total Construction Costs					\$10,105		\$19,929		\$28,619		\$40,158		\$49,788
Construction Costs Amortized for 20 Years					\$505		\$886		\$1,481		\$2,008		\$2,490
Annual Maintenance Expense													
Item	Units	Price	Cycles/Year	Quant. 1 Acres WS	Total	Quant. 2 Acres WS	Total	Quant. 3 Acres WS	Total	Quant. 4 Acres WS	Total	Quant. 5 Acres WS	Total
Sweeping	AC	\$250.00	6	1	\$1,500	2	\$3,000	3	\$4,500	4	\$6,000	5	\$7,500
Washing	AC	\$250.00	6	1	\$1,500	2	\$3,000	3	\$4,500	4	\$6,000	5	\$7,500
Inspection	MH	\$20.00	5	5	\$100	5	\$100	5	\$100	5	\$100	5	\$100
Deep Clean	AC	\$450.00	0.5	1	\$225	2	\$450	3	\$675	3.9	\$878	5	\$1,125
Total Annual Maintenance Expense					\$3,980		\$7,792		\$11,651		\$15,483		\$18,370

**Supplemental Information**

■

**Other Resources**

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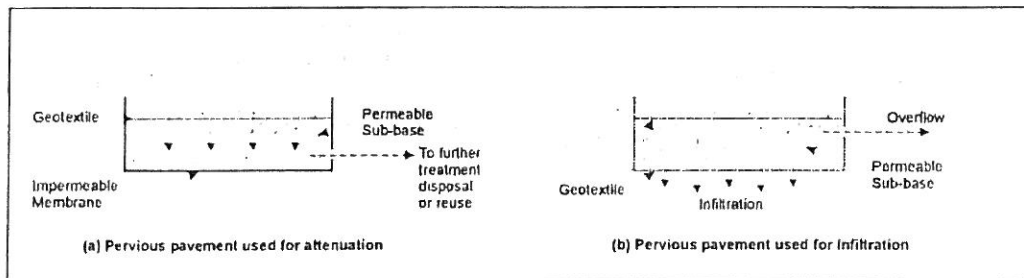
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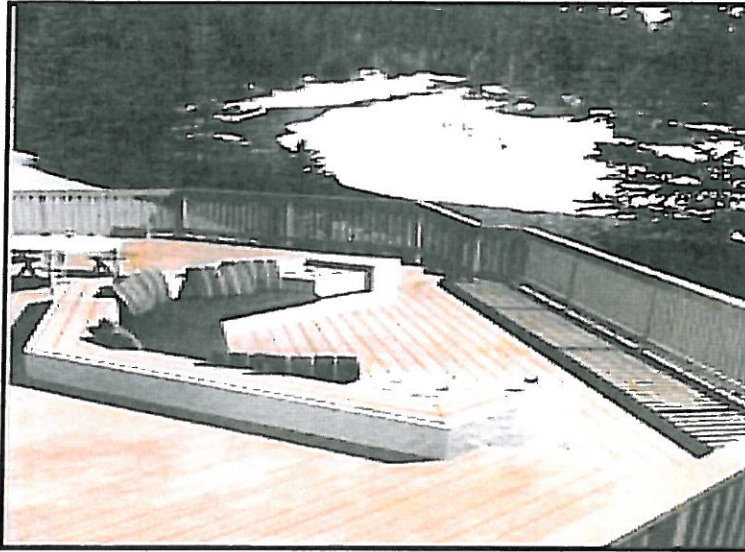
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Schlüter W. & Jefferies C. Monitoring the outflow from a *Porous Car Park Proc. First National Conference on Sustainable Drainage Systems, Coventry June 2001.*

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**Schematics of a Pervious Pavement System**



### Design Objectives

- ✓ Maximize Infiltration
- ✓ Provide Retention
- ✓ Source Control
- Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- Contain Pollutant
- Collect and Convey

### Description

Alternative building materials are selected instead of conventional materials for new construction and renovation. These materials reduce potential sources of pollutants in stormwater runoff by eliminating compounds that can leach into runoff, reducing the need for pesticide application, reducing the need for painting and other maintenance, or by reducing the volume of runoff.

### Approach

Alternative building materials are available for use as lumber for decking, roofing materials, home siding, and paving for driveways, decks, and sidewalks.

### Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment.

### Design Considerations

#### *Designing New Installations*

##### *Decking*

One of the most common materials for construction of decks and other outdoor construction has traditionally been pressure treated wood, which is now being phased out. The standard treatment is called CCA, for chromated copper arsenate. The key ingredients are arsenic (which kills termites, carpenter ants and other insects), copper (which kills the fungi that cause wood to rot) and chromium (which reacts with the other ingredients to bind them to the wood). The amount of arsenic is far from trivial. A deck just 8 feet x 10 feet contains more than 1 1/3 pounds of this highly potent poison. Replacement materials include a new type of pressure treated wood, plastic and composite lumber.

There are currently over 20 products in the market consisting of plastic or plastic-wood composites. Plastic lumber is made from 100% recycled plastic, # 2 HDPE and polyethylene plastic milk jugs



and soap bottles. Plastic-wood composites are a combination of plastic and wood fibers or sawdust. These materials are a long lasting exterior weather, insect, and chemical resistant wood lumber replacement for non structural applications. Use it for decks, docks, raised garden beds and planter boxes, pallets, hand railings, outdoor furniture, animal pens, boat decks, etc.

New pressure treated wood uses a much safer recipe, ACQ, which stands for ammoniacal copper quaternary. It contains no arsenic and no chromium. Yet the American Wood Preservers Association has found it to be just as effective as the standard formula. ACQ is common in Japan and Europe.

#### *Roofing*

Several studies have indicated that metal used as roofing material, flashing, or gutters can leach metals into the environment. The leaching occurs because rainfall is slightly acidic and slowly dissolved the exposed metals. Common traditional applications include copper sheathing and galvanized (zinc) gutters.

Coated metal products are available for both roofing and gutter applications. These products eliminate contact of bare metal with rainfall, eliminating one source of metals in runoff. There are also roofing materials made of recycled rubber and plastic that resemble traditional materials.

A less traditional approach is the use of green roofs. These roofs are not just green, they're alive. Planted with grasses and succulents, low-profile green roofs reduce the urban heat island effect, stormwater runoff, and cooling costs, while providing wildlife habitat and a connection to nature for building occupants. These roofs are widely used on industrial facilities in Europe and have been established as experimental installations in several locations in the US, including Portland, Oregon. Their feasibility is questionable in areas of California with prolonged, dry, hot weather.

#### *Paved Areas*

Traditionally, concrete is used for construction of patios, sidewalks, and driveways. Although it is non-toxic, these paved areas reduce stormwater infiltration and increase the volume and rate of runoff. This increase in the amount of runoff is the leading cause of stream channel degradation in urban areas.

There are a number of alternative materials that can be used in these applications, including porous concrete and asphalt, modular blocks, and crushed granite. These materials, especially modular paving blocks, are widely available and a well established method to reduce stormwater runoff.

#### *Building Siding*

Wood siding is commonly used on the exterior of residential construction. This material weathers fairly rapidly and requires repeated painting to prevent rotting. Alternative "new" products for this application include cement-fiber and vinyl. Cement-fiber siding is a masonry product made from Portland cement, sand, and cellulose and will not burn, cup, swell, or shrink.

#### *Pesticide Reduction*

A common use of powerful pesticides is for the control of termites. Chlordane was used for many years for this purpose and is now found in urban streams and lakes nationwide. There are a

number of physical barriers that can be installed during construction to help reduce the use of pesticides.

Sand barriers for subterranean termites are a physical deterrent because the termites cannot tunnel through it. Sand barriers can be applied in crawl spaces under pier and beam foundations, under slab foundations, and between the foundation and concrete porches, terraces, patios and steps. Other possible locations include under fence posts, underground electrical cables, water and gas lines, telephone and electrical poles, inside hollow tile cells and against retaining walls.

Metal termite shields are physical barriers to termites which prevent them from building invisible tunnels. In reality, metal shields function as a helpful termite detection device, forcing them to build tunnels on the outside of the shields which are easily seen. Metal termite shields also help prevent dampness from wicking to adjoining wood members which can result in rot, thus making the material more attractive to termites and other pests. Metal flashing and metal plates can also be used as a barrier between piers and beams of structures such as decks, which are particularly vulnerable to termite attack.

### ***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define “redevelopment” in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of “redevelopment” must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under “designing new installations” above should be followed.

### **Other Resources**

There are no good, independent, comprehensive sources of information on alternative building materials for use in minimizing the impacts of stormwater runoff. Most websites or other references to “green” or “alternative” building materials focus on indoor applications, such as formaldehyde free plywood and low VOC paints, carpets, and pads. Some supplemental information on alternative materials is available from the manufacturers.

Fires are a source of concern in many areas of California. Information on the flammability of alternative decking materials is available from the University of California Forest Product Laboratory (UCFPL) website at: <http://www.ucfpl.ucop.edu/WDDeckIntro.htm>

## Description

Trash storage areas are areas where a trash receptacle (s) are located for use as a repository for solid wastes. Stormwater runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations that may be sources of stormwater pollution include dumpsters, litter control, and waste piles.

## Approach

This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling. Preventative measures including enclosures, containment structures, and impervious pavements to mitigate spills, should be used to reduce the likelihood of contamination.

## Design Objectives

- Maximize Infiltration
- Provide Retention
- Slow Runoff
- Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- ✓ Contain Pollutants
- Collect and Convey

## Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment. (Detached residential single-family homes are typically excluded from this requirement.)

## Design Considerations

Design requirements for waste handling areas are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements. The design criteria described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled in accordance with legal requirements established in Title 22, California Code of Regulation.

Wastes from commercial and industrial sites are typically hauled by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria in this fact sheet are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection areas. Conflicts or issues should be discussed with the local agency.

## Designing New Installations

Trash storage areas should be designed to consider the following structural or treatment control BMPs:

- Design trash container areas so that drainage from adjoining roofs and pavement is diverted around the area(s) to avoid run-on. This might include berming or grading the waste handling area to prevent run-on of stormwater.
- Make sure trash container areas are screened or walled to prevent off-site transport of trash.



- Use lined bins or dumpsters to reduce leaking of liquid waste.
- Provide roofs, awnings, or attached lids on all trash containers to minimize direct precipitation and prevent rainfall from entering containers.
- Pave trash storage areas with an impervious surface to mitigate spills.
- Do not locate storm drains in immediate vicinity of the trash storage area.
- Post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define “redevelopment” in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of “redevelopment” must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under “designing new installations” above should be followed.

**Additional Information*****Maintenance Considerations***

The integrity of structural elements that are subject to damage (i.e., screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the local agency and the owner/operator may be required. Some agencies will require maintenance deed restrictions to be recorded of the property title. If required by the local agency, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved.

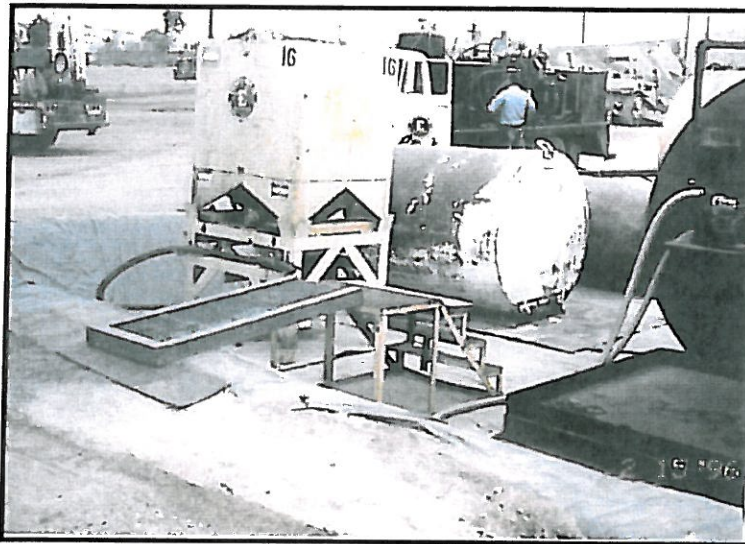
**Other Resources**

A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.

Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, February 14, 2002.

Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, Draft February 2003.

Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, July 2002.



## Design Objectives

- Maximize Infiltration
- Provide Retention
- Slow Runoff
- Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- ✓ Contain Pollutant
- Collect and Convey

## Description

Proper design of outdoor storage areas for materials reduces opportunity for toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to enter the stormwater conveyance system. Materials may be in the form of raw products, by-products, finished products, and waste products. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity.

## Approach

Outdoor storage areas require a drainage approach different from the typical infiltration/detention strategy. In outdoor storage areas, infiltration is discouraged. Containment is encouraged. Preventative measures include enclosures, secondary containment structures and impervious surfaces.

## Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment.

## Design Considerations

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials do not have to be prevented from stormwater contact. However, these materials may have toxic effects on receiving waters if allowed to be discharged with stormwater in significant quantities. Accumulated material on an impervious surface could result in significant impact on the rivers or streams that receive the runoff.

Material may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater. Control measures may also include minimizing the storage area. Design requirements



## **SD-34 Outdoor Material Storage Areas**

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for material storage areas are governed by Building and Fire Codes, and by current City or County ordinances and zoning requirements. Control measures are site specific, and must meet local agency requirements.

### ***Designing New Installations***

Where proposed project plans include outdoor areas for storage of materials that may contribute pollutants to the stormwater conveyance system, the following structural or treatment BMPs should be considered:

- Materials with the potential to contaminate stormwater should be: (1) placed in an enclosure such as, but not limited to, a cabinet, shed, or similar structure that prevents contact with runoff or spillage to the stormwater conveyance system, or (2) protected by secondary containment structures such as berms, dikes, or curbs.
- The storage area should be paved and sufficiently impervious to contain leaks and spills.
- The storage area should slope towards a dead-end sump to contain spills and direct runoff from downspouts/roofs should be directed away from storage areas.
- The storage area should have a roof or awning that extends beyond the storage area to minimize collection of stormwater within the secondary containment area. A manufactured storage shed may be used for small containers.

Note that the location(s) of installations of where these preventative measures will be employed must be included on the map or plans identifying BMPs.

### ***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define "redevelopment" in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of "redevelopment" must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under "designing new installations" above should be followed.

### **Additional Information**

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permits.

### **Other Resources**

A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.

Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, February 14, 2002.

# **Outdoor Material Storage Areas      SD-34**

Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, Draft February 2003.

Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, July 2002.



## Design Considerations

- Tributary Area
- Area Required
- Slope
- Water Availability

## Description

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. They trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. Vegetated swales can serve as part of a stormwater drainage system and can replace curbs, gutters and storm sewer systems.

## California Experience

Caltrans constructed and monitored six vegetated swales in southern California. These swales were generally effective in reducing the volume and mass of pollutants in runoff. Even in the areas where the annual rainfall was only about 10 inches/yr, the vegetation did not require additional irrigation. One factor that strongly affected performance was the presence of large numbers of gophers at most of the sites. The gophers created earthen mounds, destroyed vegetation, and generally reduced the effectiveness of the controls for TSS reduction.

## Advantages

- If properly designed, vegetated, and operated, swales can serve as an aesthetic, potentially inexpensive urban development or roadway drainage conveyance measure with significant collateral water quality benefits.

## Targeted Constituents

✓ Sediment	▲
✓ Nutrients	●
✓ Trash	●
✓ Metals	▲
✓ Bacteria	●
✓ Oil and Grease	▲
✓ Organics	▲

## Legend (Removal Effectiveness)

- Low
- High
- ▲ Medium



- Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible.

**Limitations**

- Can be difficult to avoid channelization.
- May not be appropriate for industrial sites or locations where spills may occur
- Grassed swales cannot treat a very large drainage area. Large areas may be divided and treated using multiple swales.
- A thick vegetative cover is needed for these practices to function properly.
- They are impractical in areas with steep topography.
- They are not effective and may even erode when flow velocities are high, if the grass cover is not properly maintained.
- In some places, their use is restricted by law: many local municipalities require curb and gutter systems in residential areas.
- Swales are more susceptible to failure if not properly maintained than other treatment BMPs.

**Design and Sizing Guidelines**

- Flow rate based design determined by local requirements or sized so that 85% of the annual runoff volume is discharged at less than the design rainfall intensity.
- Swale should be designed so that the water level does not exceed 2/3rds the height of the grass or 4 inches, whichever is less, at the design treatment rate.
- Longitudinal slopes should not exceed 2.5%
- Trapezoidal channels are normally recommended but other configurations, such as parabolic, can also provide substantial water quality improvement and may be easier to mow than designs with sharp breaks in slope.
- Swales constructed in cut are preferred, or in fill areas that are far enough from an adjacent slope to minimize the potential for gopher damage. Do not use side slopes constructed of fill, which are prone to structural damage by gophers and other burrowing animals.
- A diverse selection of low growing, plants that thrive under the specific site, climatic, and watering conditions should be specified. Vegetation whose growing season corresponds to the wet season are preferred. Drought tolerant vegetation should be considered especially for swales that are not part of a regularly irrigated landscaped area.
- The width of the swale should be determined using Manning's Equation using a value of 0.25 for Manning's n.

## ***Construction/Inspection Considerations***

- Include directions in the specifications for use of appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the vegetation requirements.
- Install swales at the time of the year when there is a reasonable chance of successful establishment without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be used.
- If sod tiles must be used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the swale or strip.
- Use a roller on the sod to ensure that no air pockets form between the sod and the soil.
- Where seeds are used, erosion controls will be necessary to protect seeds for at least 75 days after the first rainfall of the season.

## **Performance**

The literature suggests that vegetated swales represent a practical and potentially effective technique for controlling urban runoff quality. While limited quantitative performance data exists for vegetated swales, it is known that check dams, slight slopes, permeable soils, dense grass cover, increased contact time, and small storm events all contribute to successful pollutant removal by the swale system. Factors decreasing the effectiveness of swales include compacted soils, short runoff contact time, large storm events, frozen ground, short grass heights, steep slopes, and high runoff velocities and discharge rates.

Conventional vegetated swale designs have achieved mixed results in removing particulate pollutants. A study performed by the Nationwide Urban Runoff Program (NURP) monitored three grass swales in the Washington, D.C., area and found no significant improvement in urban runoff quality for the pollutants analyzed. However, the weak performance of these swales was attributed to the high flow velocities in the swales, soil compaction, steep slopes, and short grass height.

Another project in Durham, NC, monitored the performance of a carefully designed artificial swale that received runoff from a commercial parking lot. The project tracked 11 storms and concluded that particulate concentrations of heavy metals (Cu, Pb, Zn, and Cd) were reduced by approximately 50 percent. However, the swale proved largely ineffective for removing soluble nutrients.

The effectiveness of vegetated swales can be enhanced by adding check dams at approximately 17 meter (50 foot) increments along their length (See Figure 1). These dams maximize the retention time within the swale, decrease flow velocities, and promote particulate settling. Finally, the incorporation of vegetated filter strips parallel to the top of the channel banks can help to treat sheet flows entering the swale.

Only 9 studies have been conducted on all grassed channels designed for water quality (Table 1). The data suggest relatively high removal rates for some pollutants, but negative removals for some bacteria, and fair performance for phosphorus.

<b>Table 1 Grassed swale pollutant removal efficiency data</b>							
<b>Removal Efficiencies (% Removal)</b>							
<b>Study</b>	<b>TSS</b>	<b>TP</b>	<b>TN</b>	<b>NO<sub>3</sub></b>	<b>Metals</b>	<b>Bacteria</b>	<b>Type</b>
Caltrans 2002	77	8	67	66	83-90	-33	dry swales
Goldberg 1993	67.8	4.5	-	31.4	42-62	-100	grassed channel
Seattle Metro and Washington Department of Ecology 1992	60	45	-	-25	2-16	-25	grassed channel
Seattle Metro and Washington Department of Ecology, 1992	83	29	-	-25	46-73	-25	grassed channel
Wang et al., 1981	80	-	-	-	70-80	-	dry swale
Dorman et al., 1989	98	18	-	45	37-81	-	dry swale
Harper, 1988	87	83	84	80	88-90	-	dry swale
Kercher et al., 1983	99	99	99	99	99	-	dry swale
Harper, 1988.	81	17	40	52	37-69	-	wet swale
Koon, 1995	67	39	-	9	-35 to 6	-	wet swale

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales, although some swales appear to export soluble phosphorus (Harper, 1988; Koon, 1995). It is not clear why swales export bacteria. One explanation is that bacteria thrive in the warm swale soils.

### Siting Criteria

The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the swale system (Schueler et al., 1992). In general, swales can be used to serve areas of less than 10 acres, with slopes no greater than 5 %. Use of natural topographic lows is encouraged and natural drainage courses should be regarded as significant local resources to be kept in use (Young et al., 1996).

### Selection Criteria (NCTCOG, 1993)

- Comparable performance to wet basins
- Limited to treating a few acres
- Availability of water during dry periods to maintain vegetation
- Sufficient available land area

Research in the Austin area indicates that vegetated controls are effective at removing pollutants even when dormant. Therefore, irrigation is not required to maintain growth during dry periods, but may be necessary only to prevent the vegetation from dying.

The topography of the site should permit the design of a channel with appropriate slope and cross-sectional area. Site topography may also dictate a need for additional structural controls. Recommendations for longitudinal slopes range between 2 and 6 percent. Flatter slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity, decrease detention time, and may require energy dissipating and grade check. Steep slopes also can be managed using a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams with swales also promotes infiltration.

## **Additional Design Guidelines**

Most of the design guidelines adopted for swale design specify a minimum hydraulic residence time of 9 minutes. This criterion is based on the results of a single study conducted in Seattle, Washington (Seattle Metro and Washington Department of Ecology, 1992), and is not well supported. Analysis of the data collected in that study indicates that pollutant removal at a residence time of 5 minutes was not significantly different, although there is more variability in that data. Therefore, additional research in the design criteria for swales is needed. Substantial pollutant removal has also been observed for vegetated controls designed solely for conveyance (Barrett et al, 1998); consequently, some flexibility in the design is warranted.

Many design guidelines recommend that grass be frequently mowed to maintain dense coverage near the ground surface. Recent research (Colwell et al., 2000) has shown mowing frequency or grass height has little or no effect on pollutant removal.

## **Summary of Design Recommendations**

- 1) The swale should have a length that provides a minimum hydraulic residence time of at least 10 minutes. The maximum bottom width should not exceed 10 feet unless a dividing berm is provided. The depth of flow should not exceed 2/3rds the height of the grass at the peak of the water quality design storm intensity. The channel slope should not exceed 2.5%.
- 2) A design grass height of 6 inches is recommended.
- 3) Regardless of the recommended detention time, the swale should be not less than 100 feet in length.
- 4) The width of the swale should be determined using Manning's Equation, at the peak of the design storm, using a Manning's n of 0.25.
- 5) The swale can be sized as both a treatment facility for the design storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located "on-line." The side slopes should be no steeper than 3:1 (H:V).
- 6) Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible. If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.
- 7) Swales must be vegetated in order to provide adequate treatment of runoff. It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses. If possible, divert runoff (other than necessary irrigation) during the period of vegetation

establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

### **Maintenance**

The useful life of a vegetated swale system is directly proportional to its maintenance frequency. If properly designed and regularly maintained, vegetated swales can last indefinitely. The maintenance objectives for vegetated swale systems include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover.

Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages. Cuttings should be removed from the channel and disposed in a local composting facility. Accumulated sediment should also be removed manually to avoid concentrated flows in the swale. The application of fertilizers and pesticides should be minimal.

Another aspect of a good maintenance plan is repairing damaged areas within a channel. For example, if the channel develops ruts or holes, it should be repaired utilizing a suitable soil that is properly tamped and seeded. The grass cover should be thick; if it is not, reseed as necessary. Any standing water removed during the maintenance operation must be disposed to a sanitary sewer at an approved discharge location. Residuals (e.g., silt, grass cuttings) must be disposed in accordance with local or State requirements. Maintenance of grassed swales mostly involves maintenance of the grass or wetland plant cover. Typical maintenance activities are summarized below:

- Inspect swales at least twice annually for erosion, damage to vegetation, and sediment and debris accumulation preferably at the end of the wet season to schedule summer maintenance and before major fall runoff to be sure the swale is ready for winter. However, additional inspection after periods of heavy runoff is desirable. The swale should be checked for debris and litter, and areas of sediment accumulation.
- Grass height and mowing frequency may not have a large impact on pollutant removal. Consequently, mowing may only be necessary once or twice a year for safety or aesthetics or to suppress weeds and woody vegetation.
- Trash tends to accumulate in swale areas, particularly along highways. The need for litter removal is determined through periodic inspection, but litter should always be removed prior to mowing.
- Sediment accumulating near culverts and in channels should be removed when it builds up to 75 mm (3 in.) at any spot, or covers vegetation.
- Regularly inspect swales for pools of standing water. Swales can become a nuisance due to mosquito breeding in standing water if obstructions develop (e.g. debris accumulation, invasive vegetation) and/or if proper drainage slopes are not implemented and maintained.

## Cost

### *Construction Cost*

Little data is available to estimate the difference in cost between various swale designs. One study (SWRPC, 1991) estimated the construction cost of grassed channels at approximately \$0.25 per ft<sup>2</sup>. This price does not include design costs or contingencies. Brown and Schueler (1997) estimate these costs at approximately 32 percent of construction costs for most stormwater management practices. For swales, however, these costs would probably be significantly higher since the construction costs are so low compared with other practices. A more realistic estimate would be a total cost of approximately \$0.50 per ft<sup>2</sup>, which compares favorably with other stormwater management practices.

Table 2 Swale Cost Estimate (SEWRPC, 1991)

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization / Demobilization-Light	Swale	1	\$107	\$274	\$441	\$107	\$274	\$441
Site Preparation								
Clearing <sup>a</sup> .....	Acres	0.5	\$2,200	\$3,800	\$5,400	\$1,100	\$1,900	\$2,700
Grubbing <sup>b</sup> .....	Acres	0.25	\$3,800	\$5,200	\$6,600	\$950	\$1,300	\$1,650
General Excavation <sup>c</sup> .....	Yd <sup>3</sup>	372	\$2.10	\$3.70	\$5.30	\$781	\$1,376	\$1,972
Level and Till <sup>d</sup> .....	Yd <sup>2</sup>	1,210	\$0.20	\$0.35	\$0.50	\$242	\$424	\$605
Sites Development								
Salvaged Topsoil	Yd <sup>2</sup>	1,210	\$0.40	\$1.00	\$1.80	\$484	\$1,210	\$1,936
Seed, and Mulch ..	Yd <sup>2</sup>	1,210	\$1.20	\$2.40	\$3.60	\$1,452	\$2,904	\$4,356
Sod <sup>e</sup> .....								
Subtotal	--	--	--	--	--	\$5,116	\$9,388	\$13,660
Contingencies	Swale	1	25%	25%	25%	\$1,279	\$2,347	\$3,415
Total	--	--	--	--	--	\$6,395	\$11,735	\$17,075

Source: (SEWRPC, 1991)

Note: Mobilization/demobilization refers to the organization and planning involved in establishing a vegetative swale.

<sup>a</sup> Swale has a bottom width of 1.0 foot, a top width of 10 feet with 1:3 side slopes, and a 1,000-foot length.<sup>b</sup> Area cleared = (top width + 10 feet) x swale length.<sup>c</sup> Area grubbed = (top width x swale length).<sup>d</sup> Volume excavated = (0.67 x top width x swale depth) x swale length (parabolic cross-section).<sup>e</sup> Area filled = (top width +  $\frac{B(\text{swale depth})^2}{3(\text{top width})}$ ) x swale length (parabolic cross-section).<sup>f</sup> Area seeded = area cleared x 0.5.<sup>g</sup> Area sodded = area cleared x 0.5.

# Vegetated Swale

TC-30

Table 3 Estimated Maintenance Costs (SEWRPC, 1991)

Component	Unit Cost	Swale Size (Depth and Top Width)		Comment
		1.5 Foot Depth, One-Foot Bottom Width, 10-Foot Top Width	3-Foot Depth, 3-Foot Bottom Width, 21-Foot Top Width	
Lawn Mowing	\$0.85 / 1,000 ft <sup>2</sup> /mowing	\$0.14 / linear foot	\$0.21 / linear foot	Lawn maintenance area = (top width + 10 feet) x length. Mow eight times per year
General Lawn Care	\$0.00 / 1,000 ft <sup>2</sup> /year	\$0.18 / linear foot	\$0.28 / linear foot	Lawn maintenance area = (top width + 10 feet) x length
Swale Debris and Litter Removal	\$0.10 / linear foot / year	\$0.10 / linear foot	\$0.10 / linear foot	-
Grass Reseeding with Mulch and Fertilizer	\$0.30 / yd <sup>2</sup>	\$0.01 / linear foot	\$0.01 / linear foot	Area revegetated equals 1% of lawn maintenance area per year
Program Administration and Swale Inspection	\$0.15 / linear foot / year, plus \$25 / inspection	\$0.15 / linear foot	\$0.15 / linear foot	Inspect four times per year
Total	--	\$0.58 / linear foot	\$0.75 / linear foot	-

**Maintenance Cost**

Caltrans (2002) estimated the expected annual maintenance cost for a swale with a tributary area of approximately 2 ha at approximately \$2,700. Since almost all maintenance consists of mowing, the cost is fundamentally a function of the mowing frequency. Unit costs developed by SEWRPC are shown in Table 3. In many cases vegetated channels would be used to convey runoff and would require periodic mowing as well, so there may be little additional cost for the water quality component. Since essentially all the activities are related to vegetation management, no special training is required for maintenance personnel.

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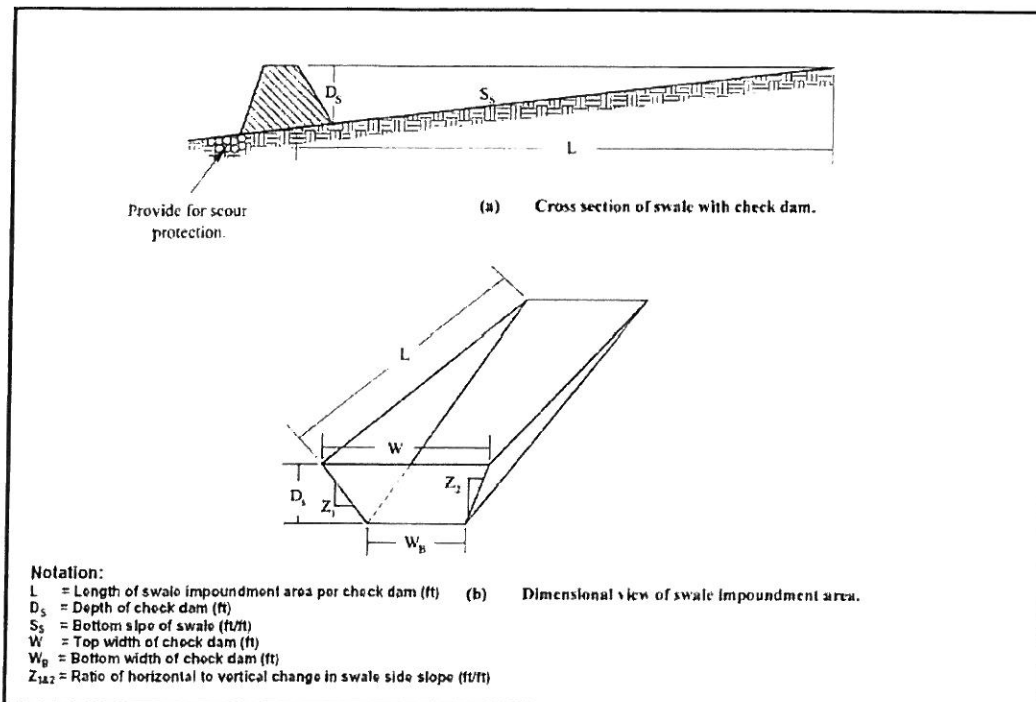
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# Infiltration Trench

TC-10



## Design Considerations

- Accumulation of Metals
- Clogged Soil Outlet Structures
- Vegetation/Landscape Maintenance

## Description

An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff. Runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. Infiltration trenches perform well for removal of fine sediment and associated pollutants.

Pretreatment using buffer strips, swales, or detention basins is important for limiting amounts of coarse sediment entering the trench which can clog and render the trench ineffective.

## California Experience

Caltrans constructed two infiltration trenches at highway maintenance stations in Southern California. Of these, one failed to operate to the design standard because of average soil infiltration rates lower than that measured in the single infiltration test. This highlights the critical need for appropriate evaluation of the site. Once in operation, little maintenance was required at either site.

## Advantages

- Provides 100% reduction in the load discharged to surface waters.
- An important benefit of infiltration trenches is the approximation of pre-development hydrology during which a significant portion of the average annual rainfall runoff is infiltrated rather than flushed directly to creeks.
- If the water quality volume is adequately sized, infiltration trenches can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.

## Targeted Constituents

✓	Sediment	■
✓	Nutrients	■
✓	Trash	■
✓	Metals	■
✓	Bacteria	■
✓	Oil and Grease	■
✓	Organics	■

## Legend (Removal Effectiveness)

- Low
- High
- ▲ Medium



- As an underground BMP, trenches are unobtrusive and have little impact of site aesthetics.

## Limitations

- Have a high failure rate if soil and subsurface conditions are not suitable.
- May not be appropriate for industrial sites or locations where spills may occur.
- The maximum contributing area to an individual infiltration practice should generally be less than 5 acres.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C and D.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.
- Not suitable on fill sites or steep slopes.
- Risk of groundwater contamination in very coarse soils.
- Upstream drainage area must be completely stabilized before construction.
- Difficult to restore functioning of infiltration trenches once clogged.

## Design and Sizing Guidelines

- Provide pretreatment for infiltration trenches in order to reduce the sediment load. Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. Pretreatment is important for all structural stormwater management practices, but it is particularly important for infiltration practices. To ensure that pretreatment mechanisms are effective, designers should incorporate practices such as grassed swales, vegetated filter strips, detention, or a plunge pool in series.
- Specify locally available trench rock that is 1.5 to 2.5 inches in diameter.
- Determine the trench volume by assuming the WQV will fill the void space based on the computed porosity of the rock matrix (normally about 35%).
- Determine the bottom surface area needed to drain the trench within 72 hr by dividing the WQV by the infiltration rate.

$$d = \frac{WQV + RFV}{SA}$$

- Calculate trench depth using the following equation:

where:

D = Trench depth

WQV	=	Water quality volume
RFV	=	Rock fill volume
SA	=	Surface area of the trench bottom

- The use of vertical piping, either for distribution or infiltration enhancement shall not be allowed to avoid device classification as a Class V injection well per 40 CFR146.5(e)(4).
- Provide observation well to allow observation of drain time.
- May include a horizontal layer of filter fabric just below the surface of the trench to retain sediment and reduce the potential for clogging.

## ***Construction/Inspection Considerations***

Stabilize the entire area draining to the facility before construction begins. If impossible, place a diversion berm around the perimeter of the infiltration site to prevent sediment entrance during construction. Stabilize the entire contributing drainage area before allowing any runoff to enter once construction is complete.

## **Performance**

Infiltration trenches eliminate the discharge of the water quality volume to surface receiving waters and consequently can be considered to have 100% removal of all pollutants within this volume. Transport of some of these constituents to groundwater is likely, although the attenuation in the soil and subsurface layers will be substantial for many constituents.

Infiltration trenches can be expected to remove up to 90 percent of sediments, metals, coliform bacteria and organic matter, and up to 60 percent of phosphorus and nitrogen in the infiltrated runoff (Schueler, 1992). Biochemical oxygen demand (BOD) removal is estimated to be between 70 to 80 percent. Lower removal rates for nitrate, chlorides and soluble metals should be expected, especially in sandy soils (Schueler, 1992). Pollutant removal efficiencies may be improved by using washed aggregate and adding organic matter and loam to the subsoil. The stone aggregate should be washed to remove dirt and fines before placement in the trench. The addition of organic material and loam to the trench subsoil may enhance metals removal through adsorption.

## **Siting Criteria**

The use of infiltration trenches may be limited by a number of factors, including type of native soils, climate, and location of groundwater table. Site characteristics, such as excessive slope of the drainage area, fine-grained soil types, and proximate location of the water table and bedrock, may preclude the use of infiltration trenches. Generally, infiltration trenches are not suitable for areas with relatively impermeable soils containing clay and silt or in areas with fill.

As with any infiltration BMP, the potential for groundwater contamination must be carefully considered, especially if the groundwater is used for human consumption or agricultural purposes. The infiltration trench is not suitable for sites that use or store chemicals or hazardous materials unless hazardous and toxic materials are prevented from entering the trench. In these areas, other BMPs that do not allow interaction with the groundwater should be considered.

The potential for spills can be minimized by aggressive pollution prevention measures. Many municipalities and industries have developed comprehensive spill prevention control and countermeasure (SPCC) plans. These plans should be modified to include the infiltration trench and the contributing drainage area. For example, diversion structures can be used to prevent spills from entering the infiltration trench. Because of the potential to contaminate groundwater, extensive site investigation must be undertaken early in the site planning process to establish site suitability for the installation of an infiltration trench.

Longevity can be increased by careful geotechnical evaluation prior to construction and by designing and implementing an inspection and maintenance plan. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration trench. Pretreatment structures, such as a vegetated buffer strip or water quality inlet, can increase longevity by removing sediments, hydrocarbons, and other materials that may clog the trench. Regular maintenance, including the replacement of clogged aggregate, will also increase the effectiveness and life of the trench.

Evaluation of the viability of a particular site is the same as for infiltration basins and includes:

- Determine soil type (consider RCS soil type 'A, B or C' only) from mapping and consult USDA soil survey tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high water table, and estimated permeability. The soil should not have more than 30 percent clay or more than 40 percent of clay and silt combined. Eliminate sites that are clearly unsuitable for infiltration.
- Groundwater separation should be at least 3 m from the basin invert to the measured ground water elevation. There is concern at the state and regional levels of the impact on groundwater quality from infiltrated runoff, especially when the separation between groundwater and the surface is small.
- Location away from buildings, slopes and highway pavement (greater than 6 m) and wells and bridge structures (greater than 30 m). Sites constructed of fill, having a base flow or with a slope greater than 15 percent should not be considered.
- Ensure that adequate head is available to operate flow splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.
- Base flow should not be present in the tributary watershed.

#### ***Secondary Screening Based on Site Geotechnical Investigation***

- At least three in-hole conductivity tests shall be performed using USBR 7300-89 or Bouwer-Rice procedures (the latter if groundwater is encountered within the boring), two tests at different locations within the proposed basin and the third down gradient by no more than approximately 10 m. The tests shall measure permeability in the side slopes and the bed within a depth of 3 m of the invert.
- The minimum acceptable hydraulic conductivity as measured in any of the three required test holes is 13 mm/hr. If any test hole shows less than the minimum value, the site should be disqualified from further consideration.

- Exclude from consideration sites constructed in fill or partially in fill unless no silts or clays are present in the soil boring. Fill tends to be compacted, with clays in a dispersed rather than flocculated state, greatly reducing permeability.
- The geotechnical investigation should be such that a good understanding is gained as to how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water.

## Maintenance

Infiltration trenches required the least maintenance of any of the BMPs evaluated in the Caltrans study, with approximately 17 field hours spent on the operation and maintenance of each site. Inspection of the infiltration trench was the largest field activity, requiring approximately 8 hr/yr.

In addition to reduced water quality performance, clogged infiltration trenches with surface standing water can become a nuisance due to mosquito breeding. If the trench takes more than 72 hours to drain, then the rock fill should be removed and all dimensions of the trench should be increased by 2 inches to provide a fresh surface for infiltration.

## Cost

### Construction Cost

Infiltration trenches are somewhat expensive, when compared to other stormwater practices, in terms of cost per area treated. Typical construction costs, including contingency and design costs, are about \$5 per ft<sup>3</sup> of stormwater treated (SWRPC, 1991; Brown and Schueler, 1997). Actual construction costs may be much higher. The average construction cost of two infiltration trenches installed by Caltrans in southern California was about \$50/ft<sup>3</sup>; however, these were constructed as retrofit installations.

Infiltration trenches typically consume about 2 to 3 percent of the site draining to them, which is relatively small. In addition, infiltration trenches can fit into thin, linear areas. Thus, they can generally fit into relatively unusable portions of a site.

### Maintenance Cost

One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly sited or maintained, infiltration trenches have a high failure rate. In general, maintenance costs for infiltration trenches are estimated at between 5 percent and 20 percent of the construction cost. More realistic values are probably closer to the 20-percent range, to ensure long-term functionality of the practice.

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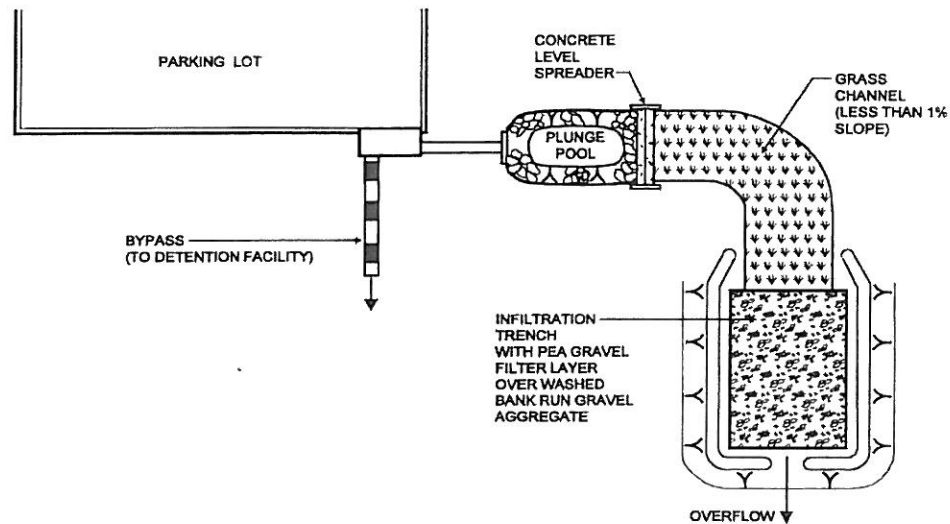
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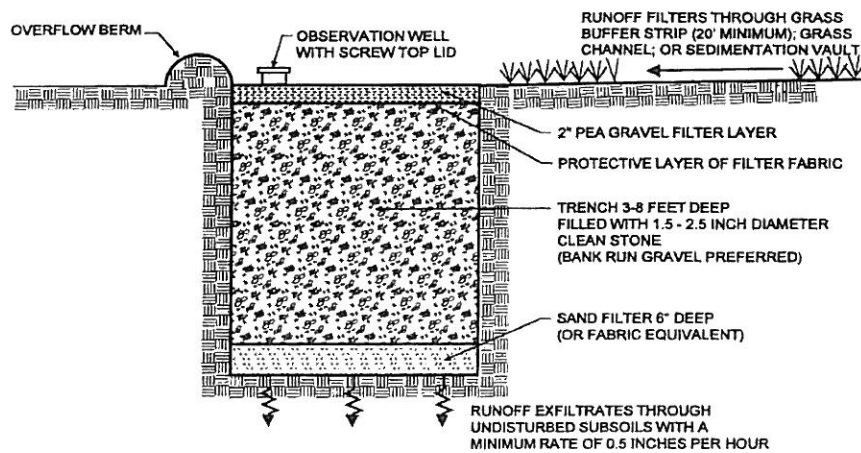
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# Infiltration Trench

TC-10



PLAN VIEW



SECTION

# Vegetated Buffer Strip

TC-31



## Design Considerations

- Tributary Area
- Slope
- Water Availability
- Aesthetics

## Description

Grassed buffer strips (vegetated filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and allowing sediment and other pollutants to settle and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide relatively high pollutant removal. In addition, the public views them as landscaped amenities and not as stormwater infrastructure. Consequently, there is little resistance to their use.

## California Experience

Caltrans constructed and monitored three vegetated buffer strips in southern California and is currently evaluating their performance at eight additional sites statewide. These strips were generally effective in reducing the volume and mass of pollutants in runoff. Even in the areas where the annual rainfall was only about 10 inches/yr, the vegetation did not require additional irrigation. One factor that strongly affected performance was the presence of large numbers of gophers at most of the southern California sites. The gophers created earthen mounds, destroyed vegetation, and generally reduced the effectiveness of the controls for TSS reduction.

## Advantages

- Buffers require minimal maintenance activity (generally just erosion prevention and mowing).
- If properly designed, vegetated, and operated, buffer strips can provide reliable water quality benefits in conjunction with high aesthetic appeal.

## Targeted Constituents

✓	Sediment	■
✓	Nutrients	●
✓	Trash	▲
✓	Metals	■
✓	Bacteria	●
✓	Oil and Grease	■
✓	Organics	▲

### Legend (Removal Effectiveness)

- Low
- High
- ▲ Medium



- Flow characteristics and vegetation type and density can be closely controlled to maximize BMP effectiveness.
- Roadside shoulders act as effective buffer strips when slope and length meet criteria described below.

**Limitations**

- May not be appropriate for industrial sites or locations where spills may occur.
- Buffer strips cannot treat a very large drainage area.
- A thick vegetative cover is needed for these practices to function properly.
- Buffer or vegetative filter length must be adequate and flow characteristics acceptable or water quality performance can be severely limited.
- Vegetative buffers may not provide treatment for dissolved constituents except to the extent that flows across the vegetated surface are infiltrated into the soil profile.
- This technology does not provide significant attenuation of the increased volume and flow rate of runoff during intense rain events.

**Design and Sizing Guidelines**

- Maximum length (in the direction of flow towards the buffer) of the tributary area should be 60 feet.
- Slopes should not exceed 15%.
- Minimum length (in direction of flow) is 15 feet.
- Width should be the same as the tributary area.
- Either grass or a diverse selection of other low growing, drought tolerant, native vegetation should be specified. Vegetation whose growing season corresponds to the wet season is preferred.

**Construction/Inspection Considerations**

- Include directions in the specifications for use of appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the vegetation requirements.
- Install strips at the time of the year when there is a reasonable chance of successful establishment without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be required.
- If sod tiles must be used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the strip.
- Use a roller on the sod to ensure that no air pockets form between the sod and the soil.

- Where seeds are used, erosion controls will be necessary to protect seeds for at least 75 days after the first rainfall of the season.

## Performance

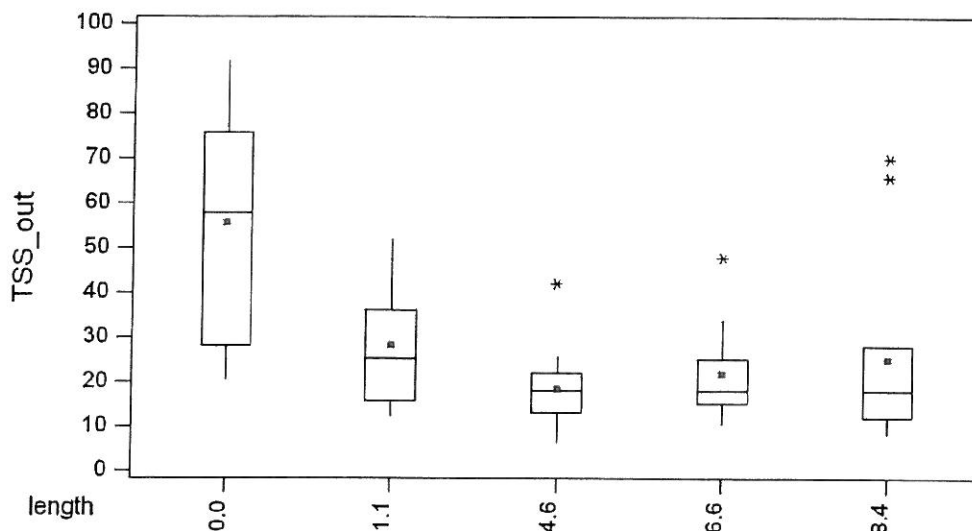
Vegetated buffer strips tend to provide somewhat better treatment of stormwater runoff than swales and have fewer tendencies for channelization or erosion. Table 1 documents the pollutant removal observed in a recent study by Caltrans (2002) based on three sites in southern California. The column labeled "Significance" is the probability that the mean influent and effluent EMCs are not significantly different based on an analysis of variance.

The removal of sediment and dissolved metals was comparable to that observed in much more complex controls. Reduction in nitrogen was not significant and all of the sites exported phosphorus for the entire study period. This may have been the result of using salt grass, a warm weather species that is dormant during the wet season, and which leaches phosphorus when dormant.

Another Caltrans study (unpublished) of vegetated highway shoulders as buffer strips also found substantial reductions often within a very short distance of the edge of pavement. Figure 1 presents a box and whisker plot of the concentrations of TSS in highway runoff after traveling various distances (shown in meters) through a vegetated filter strip with a slope of about 10%. One can see that the TSS median concentration reaches an irreducible minimum concentration of about 20 mg/L within 5 meters of the pavement edge.

**Table 1 Pollutant Reduction in a Vegetated Buffer Strip**

Constituent	Mean EMC		Removal %	Significance P
	Influent (mg/L)	Effluent (mg/L)		
TSS	119	31	74	<0.000
NO <sub>3</sub> -N	0.67	0.58	13	0.367
TKN-N	2.50	2.10	16	0.542
Total N <sup>a</sup>	3.17	2.68	15	-
Dissolved P	0.15	0.46	-206	0.047
Total P	0.42	0.62	-52	0.035
Total Cu	0.058	0.009	84	<0.000
Total Pb	0.046	0.006	88	<0.000
Total Zn	0.245	0.055	78	<0.000
Dissolved Cu	0.029	0.007	77	0.004
Dissolved Pb	0.004	0.002	66	0.006
Dissolved Zn	0.099	0.035	65	<0.000



Filter strips also exhibit good removal of litter and other floatables because the water depth in these systems is well below the vegetation height and consequently these materials are not easily transported through them. Unfortunately little attenuation of peak runoff rates and volumes (particularly for larger events) is normally observed, depending on the soil properties. Therefore it may be prudent to follow the strips with another practice than can reduce flooding and channel erosion downstream.

### Siting Criteria

The use of buffer strips is limited to gently sloping areas where the vegetative cover is robust and diffuse, and where shallow flow characteristics are possible. The practical water quality benefits can be effectively eliminated with the occurrence of significant erosion or when flow concentration occurs across the vegetated surface. Slopes should not exceed 15 percent or be less than 1 percent. The vegetative surface should extend across the full width of the area being drained. The upstream boundary of the filter should be located contiguous to the developed area. Use of a level spreading device (vegetated berm, sawtooth concrete border, rock trench, etc) to facilitate overland sheet flow is not normally recommended because of maintenance considerations and the potential for standing water.

Filter strips are applicable in most regions, but are restricted in some situations because they consume a large amount of space relative to other practices. Filter strips are best suited to treating runoff from roads and highways, roof downspouts, small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer or as pretreatment to a structural practice. In arid areas, however, the cost of irrigating the grass on the practice will most likely outweigh its water quality benefits, although aesthetic considerations may be sufficient to overcome this constraint. Filter strips are generally impractical in ultra-urban areas where little pervious surface exists.

Some cold water species, such as trout, are sensitive to changes in temperature. While some treatment practices, such as wet ponds, can warm stormwater substantially, filter strips do not

are not expected to increase stormwater temperatures. Thus, these practices are good for protection of cold-water streams.

Filter strips should be separated from the ground water by between 2 and 4 ft to prevent contamination and to ensure that the filter strip does not remain wet between storms.

## Additional Design Guidelines

Filter strips appear to be a minimal design practice because they are basically no more than a grassed slope. In general the slope of the strip should not exceed 15% and the strip should be at least 15 feet long to provide water quality treatment. Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion. The top of the strip should be installed 2-5 inches below the adjacent pavement, so that vegetation and sediment accumulation at the edge of the strip does not prevent runoff from entering.

A major question that remains unresolved is how large the drainage area to a strip can be. Research has conclusively demonstrated that these are effective on roadside shoulders, where the contributing area is about twice the buffer area. They have also been installed on the perimeter of large parking lots where they performed fairly effectively; however much lower slopes may be needed to provide adequate water quality treatment.

The filter area should be densely vegetated with a mix of erosion-resistant plant species that effectively bind the soil. Native or adapted grasses, shrubs, and trees are preferred because they generally require less fertilizer and are more drought resistant than exotic plants. Runoff flow velocities should not exceed about 1 fps across the vegetated surface.

For engineered vegetative strips, the facility surface should be graded flat prior to placement of vegetation. Initial establishment of vegetation requires attentive care including appropriate watering, fertilization, and prevention of excessive flow across the facility until vegetation completely covers the area and is well established. Use of a permanent irrigation system may help provide maximal water quality performance.

In cold climates, filter strips provide a convenient area for snow storage and treatment. If used for this purpose, vegetation in the filter strip should be salt-tolerant (e.g., creeping bentgrass), and a maintenance schedule should include the removal of sand built up at the bottom of the slope. In arid or semi-arid climates, designers should specify drought-tolerant grasses to minimize irrigation requirements.

## Maintenance

Filter strips require mainly vegetation management; therefore little special training is needed for maintenance crews. Typical maintenance activities and frequencies include:

- Inspect strips at least twice annually for erosion or damage to vegetation, preferably at the end of the wet season to schedule summer maintenance and before major fall run-off to be sure the strip is ready for winter. However, additional inspection after periods of heavy run-off is most desirable. The strip should be checked for debris and litter and areas of sediment accumulation.
- Recent research on biofiltration swales, but likely applicable to strips (Colwell et al., 2000), indicates that grass height and mowing frequency have little impact on pollutant removal;

consequently, mowing may only be necessary once or twice a year for safety and aesthetics or to suppress weeds and woody vegetation.

- Trash tends to accumulate in strip areas, particularly along highways. The need for litter removal should be determined through periodic inspection but litter should always be removed prior to mowing.
- Regularly inspect vegetated buffer strips for pools of standing water. Vegetated buffer strips can become a nuisance due to mosquito breeding in level spreaders (unless designed to dewater completely in 48-72 hours), in pools of standing water if obstructions develop (e.g. debris accumulation, invasive vegetation), and/or if proper drainage slopes are not implemented and maintained.

### Cost

#### Construction Cost

Little data is available on the actual construction costs of filter strips. One rough estimate can be the cost of seed or sod, which is approximately 30¢ per ft<sup>2</sup> for seed or 70¢ per ft<sup>2</sup> for sod. This amounts to between \$13,000 and \$30,000 per acre of filter strip. This cost is relatively high compared with other treatment practices. However, the grassed area used as a filter strip may have been seeded or sodded even if it were not used for treatment. In these cases, the only additional cost is the design. Typical maintenance costs are about \$350/acre/year (adapted from SWRPC, 1991). This cost is relatively inexpensive and, again, might overlap with regular landscape maintenance costs.

The true cost of filter strips is the land they consume. In some situations this land is available as wasted space beyond back yards or adjacent to roadsides, but this practice is cost-prohibitive when land prices are high and land could be used for other purposes.

#### Maintenance Cost

Maintenance of vegetated buffer strips consists mainly of vegetation management (mowing, irrigation if needed, weeding) and litter removal. Consequently the costs are quite variable depending on the frequency of these activities and the local labor rate.

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